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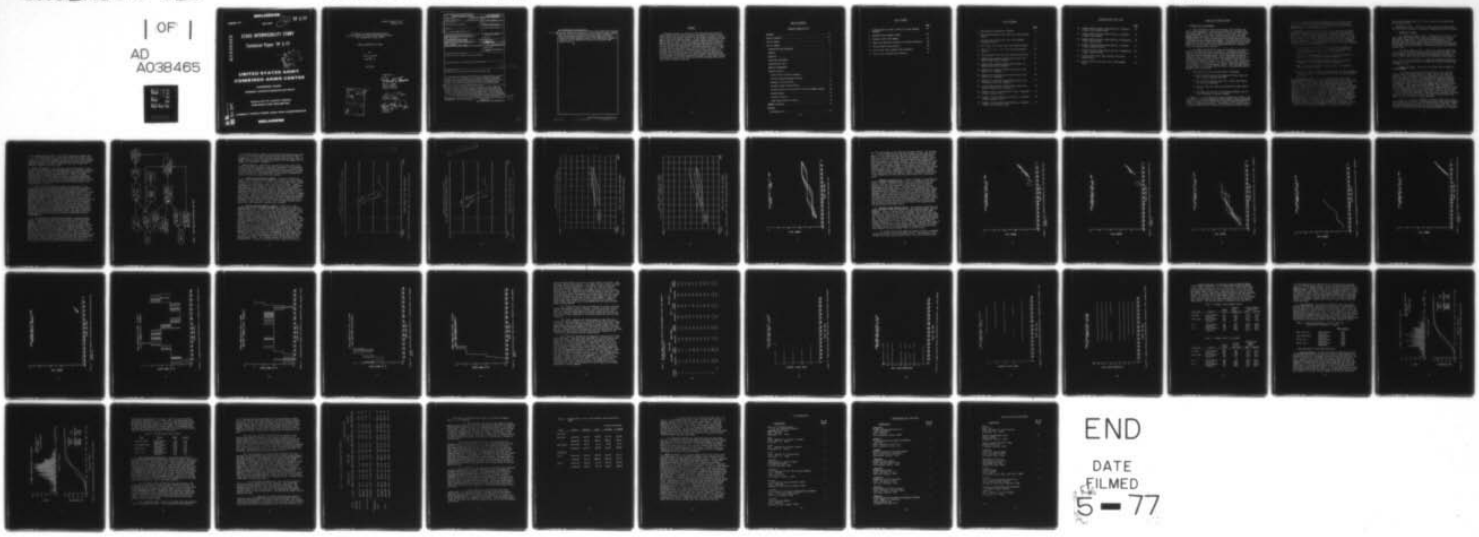

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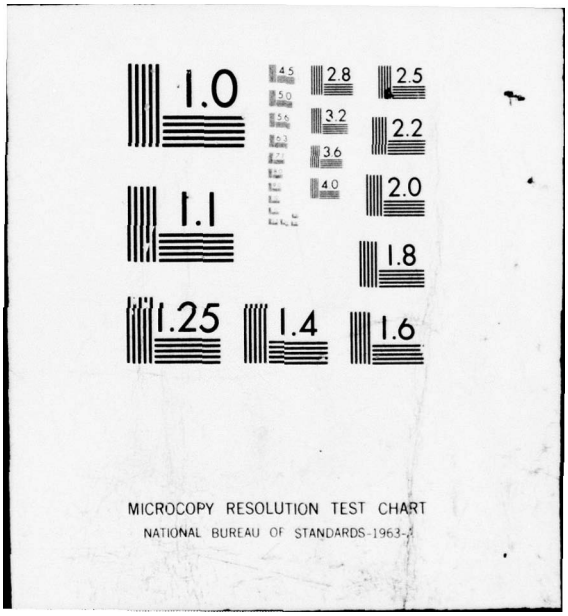
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STAGS INTERVISIBILITY STUDY

Technical Paper TP 2-77

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COMBAT DEVELOPMENTS ACTIVITY

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Directorate of Combat Operations Analysis
US Army Combined Arms Combat Developments Activity
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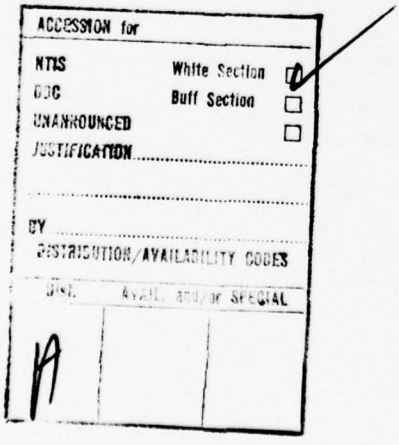

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This paper contains an analysis of the data collected during the STAGS Intervisibility Study to evaluate the potential effects of differing tactics and terrain selection on the target presented to the gunners of crew served weapon systems. A tank platoon, consisting of five M60A1 tanks ran trials using two different approach tactics over two varying terrain sites. Tactics included the rapid advance approach of FM 17-15 and the bounding overwatch technique outlined in TC 17-15-3. The two terrain sites consisted of the wooded areas found at → next page

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Fort Knox, Kentucky and the open desert terrain at Fort Bliss, Texas. Line-of-sight data collected on a continuous basis from a maximum 10 observer positions and 5 laser receivers during each trial provided a means of correlating multiple target intervisibility with actual dynamic sequencing of tactical movement and allowed a comparative analysis of the intervisibility recorded by an observer with the intervisibility recorded from a point source laser mounted on a tank.

ABSTRACT

This paper contains an analysis of the data collected during the STAGS Intervisibility Study to evaluate the potential effects of differing tactics and terrain selection on the target presented to the gunners of crew served weapon systems. A tank platoon, consisting of five M60A1 tanks, ran trials using two different approach tactics over two varying terrain sites. Tactics included the rapid advance approach of FM 17-15 and the bounding overwatch technique outlined in TC 17-15-3. The two terrain sites consisted of the wooded areas found at Fort Knox, Kentucky and the open desert type terrain at Fort Bliss, Texas. Line-of-sight data collected on a continuous basis from a maximum of 10 defender positions during each trial provided a means of correlating multiple target intervisibility with actual dynamic sequencing of tactical movement and allowed a comparative analysis of the intervisibility recorded by an observer with the intervisibility recorded from a point source laser mounted on the tank.

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STAGS INTERVISIBILITY STUDY

1. INTRODUCTION AND BACKGROUND.

a. The development of direct fire weapons, radar systems, and night vision equipment has been based on a need for increased detection range capabilities. With the advent of long range, laser guided weapons requiring a "continuous" uninterrupted line of sight (LOS) between gunner and target, the duration and interruption of target intervisibility in a tactical environment have become important factors in present and future weapons development. The correlation of multiple target intervisibility with actual dynamic sequencing of tactical movement is an area of intervisibility measurement that has continued to elude the experimentation community.

b. The STAGS Intervisibility Study was developed in an effort to describe in detail the target presented by a tank maneuvering under tactical type conditions and to determine the influence of terrain and vegetation on the presented target. The US Army Human Engineering Laboratory (HEL) at Aberdeen Proving Ground, Maryland was selected to conduct the intervisibility portion of the Swedish S-Tank Agility/ Survivability (STAGS) Evaluation as a part of their study of the potential effects of differing tactics and terrain selection as presented to the gunners of crew served weapons systems. The experiment was conducted at Fort Knox, Kentucky and Fort Bliss, Texas during the period November 1975 to March 1976.

c. The objectives of the experiment were to determine:

- when intervisibility exists between the target tanks and any of several defender positions
- the distance along the course that a target tank remains in view for any defender
- the time along the course during which the target remains in view
- the number and duration of simultaneous defender line-of-sight conditions to multiple targets.

2. PURPOSE.

The Combat Operations Analysis Directorate (COAD) of the Combined Arms Combat Developments Activity (CACDA) at Fort Leavenworth, Kansas has been active in the study of tactical intervisibility as it relates to weapons effectiveness. The purpose of this analysis was to investigate the duration of intervisibility during a realistic threat

approach, to determine the uses and effects that varying tactics and terrain have for this target intervisibility, and to examine the interaction of platoon elements as it relates to the intervisibility between defenders and advancing targets.

3. OBJECTIVE. One of the primary steps in this study was reconstruction of the geometry and time sequence as it actually occurred during each trial. This reconstruction provides an empirical means of validating the results of combat simulation models. For example, the STAGS intervisibility trails can be compared with the results of various LOS drivers to determine if the models represent target tactical movement and intervisibility in a reasonable manner. Specific questions addressed by the analysis include the following:

- How does the intervisibility status of a target recorded by a laser receiver differ from the intervisibility of that same target recorded by an observer at the same position?
- What is the average amount of time an attacking element(s) is visible to a single and/or multiple defender(s)?
- What is the average visible segment length of an attacking element(s) to a single and/or multiple defender(s)?
- What is the average number of tanks visible to a defender at any given point in time?
- How does a change in tactic or terrain affect the intervisibility that occurs between an advancing threat array and given defender positions?

4. SCOPE AND LIMITATIONS. The intervisibility data used in this analysis were collected during the intervisibility portion of the S-Tank Agility/Survivability (STAGS) Study conducted at Fort Knox and Fort Bliss. Intervisibility status was collected from 10 defender sites chosen to simulate tactical positions that would be used by a stationary tank (four positions), four simulating crew served weapon systems sites (TOW and DRAGON), and two helicopter hover points (TOW/COBRA). Prior to execution of each trial, the platoon leader was given a mission to attack, seize, and secure an objective. The only constraint placed on the threat force was to use a specific tactic, either rapid advance or bounding overwatch, throughout the trial. Intervisibility measurements were taken on a continuous basis and are dependent on the individual observer's ability to determine when a target was in his LOS. At Fort Knox defender-to-target ranges did not exceed 2,000 meters, while at Fort Bliss this range was extended to a maximum of 4,500 meters.

Trials were conducted using both tactics in each of two varying areas on each terrain site.

5. DESCRIPTION OF DATA. Definition of terms used in the data collection and the test procedure is necessary to understanding of the analysis.

a. Definition of Terms.

(1) Bounding overwatch tactic. (Outlined in TC 17-15-3.) The tank platoon was divided into a light and a heavy section of two and three tanks, respectively. As one section moved forward to a firing position, the other section would remain to provide covering fire. When the moving section reached its position, it would go into overwatch as the other section moved forward. Each section was to use terrain for maximum cover.

(2) Rapid advance tactics. (FM 17-15.) Tanks are employed so that maximum use is made of their battlefield mobility and speed. The rate of advance should be the maximum rate permitted by the terrain, with the entire force using the same axis of approach to the objective.

(3) Line of sight (LOS). A target was recorded as being in a defender's LOS if any portion of the target vehicle was visible through the weapon's sight.

b. Conduct of Trials. Each trial was divided into two phases as described below.

(1) Prior to the execution of each Phase I trial, the tank platoon leader was given a mission to attack, seize, and secure an objective. The only constraint on the platoon was to use a specific tactic throughout the trial. The path each tank traveled during this free-play phase was marked every 10 seconds by a controller dropping consecutively numbered blocks from the loader's position of the tank. Following each trial run, the distance between each block was measured and recorded. Stakes were placed approximately every 100 meters or when an aspect change occurred. Each stake was numbered and color-coded for the corresponding tank. Aerial photos were taken at the Fort Knox sites from which stake coordinates were taken. The Fort Bliss trails had to be surveyed for these data. These procedures provided an accurate measure of the path length traveled, the rates of advance during the trial, and trail tracings with map coordinates.

(2) Phase II of the experiment collected intervisibility data from the observer positions. A tank retraced each attack route following the numbered stakes at as close to 5 miles per hour as possible. Every observer recorded when the tank came into his LOS and when it went out of LOS by pressing a button that relayed the information to a 20-channel

Esterline-Angus event recorder. This device records time events from up to 20 different sources on a strip chart calibrated so that 1 inch on the chart represented 10 seconds of trial time. As the tank traveled a given path, the time at which it passed each stake was also recorded. From this procedure the amount of time each tank was visible to an individual observer could be derived.

6. ANALYSIS METHODOLOGY. The data base used for the analysis is the result of some elementary data transformations and simple data reduction methods. As seen in figure 1, six basic data sources were used, four from the Phase I trials and two from Phase II. Phase I provided measured distances between stakes and blocks and the map coordinates of each stake. Time of visibility along each tank path and the time the tank passed each stake along its trail were taken in Phase II trials. Every change in intervisibility was digitized and transformed to the corresponding time interval.

a. Due to velocity differences between the two phases, it was necessary to set up a correlation between the visibility time base and the distance base of the attack trials. One factor was constant in both trials--that being the distance traveled between stakes. This fact allowed for determination of the time it would have taken to traverse each block distance during the intervisibility trials with a ratio of that block distance to the stake distance in which it occurred multiplied by the time it took to travel that stake distance (from the Phase II data). Time consuming sum-subtraction accounting and ratios between the visibility times and the translated times for the block intervals allowed the actual visibility status during each block interval to be calculated. Finally, it was necessary to transform these times back into the time sequencing of the attack trials. The ratio of digitized visibility times to the translated block visibility times multiplied by the attack trial block time of 10 seconds accomplished the final transformation.

b. The reduced data base available provides a second-by-second account of each target's visibility status during a realistic platoon advance. Dividing each block distance by 10 results in a velocity profile of the varying advance rates that occur over an attack route. Knowledge of how the elements of a platoon interact with each other and their terrain can be gained from plots of the dynamic geometry. Overlaying the intervisibility time segments on these trails affords a view of the interaction of tactics and terrain and the effect an observer's position has on the amount of target visibility. These interactions and the correlation of multiple target intervisibility with actual dynamic sequencing of target movement are contained within the transformed data base. Intervisibility data collected from five point-source laser receivers and intervisibility data collected from five observers at the

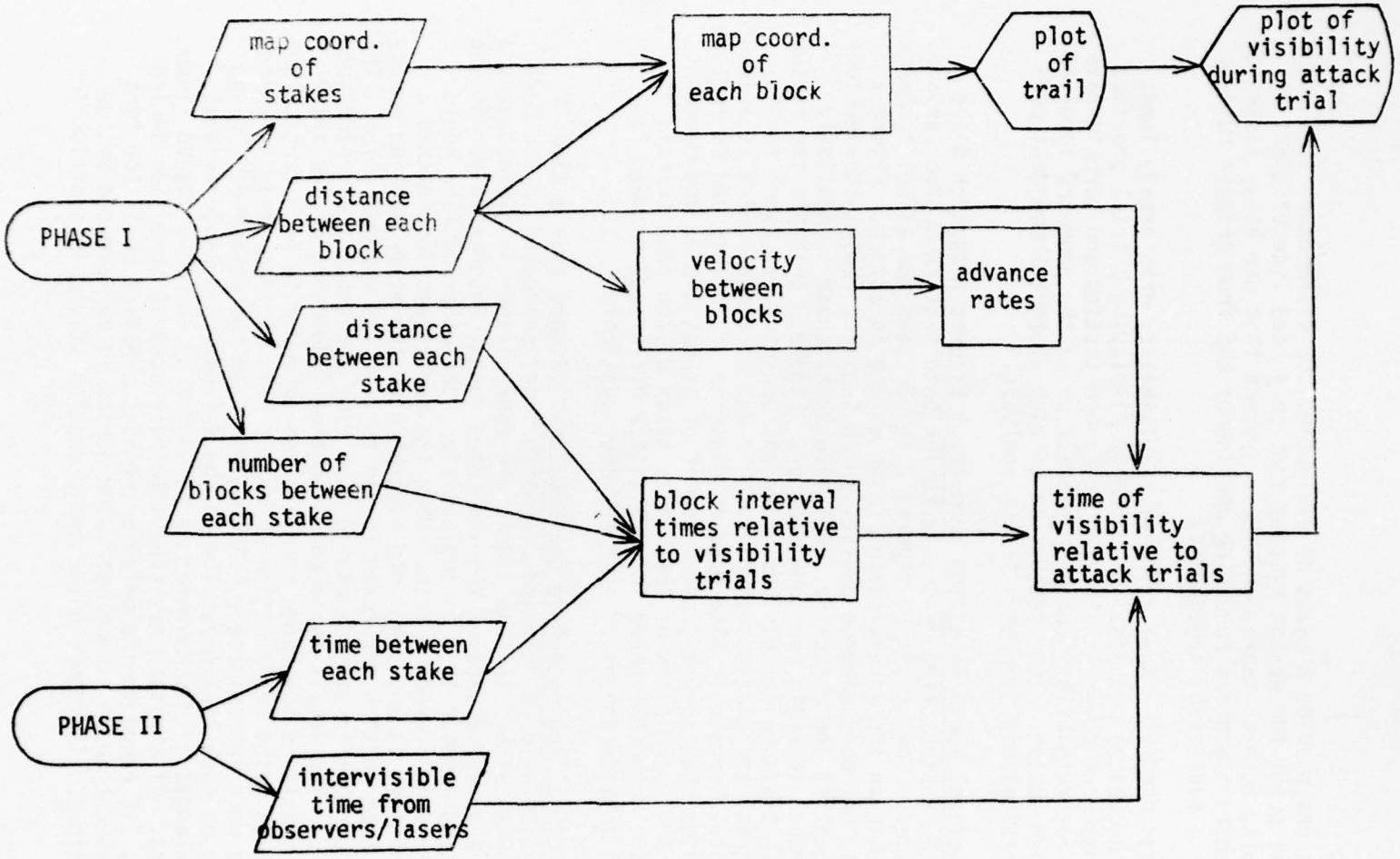

Figure 1. Data reduction methodology flow chart

same positions provide a means of evaluating LOS differences that occur at the same point for weapon systems that only need line of sight at trigger pull, such as tanks, and those systems that use heat, laser, or optical contrast seekers requiring continuous LOS from trigger pull to impact for a successful engagement.

7. ANALYSIS RESULTS. Analysis of intervisibility data easily lends itself to graphical methods. Graphically displaying a trial provides a visual means of comprehending the influence tactics and terrain have on target intervisibility and an appreciation of the geometry involved in a platoon action. Time sequencing of each element's movement provides a critical new dimension to the analysis.

a. Tactical Route Selection Geometry. Figures 2 through 5 are plots of the routes taken by the tanks for both tactics on two varying terrain sites. Comparison of figures 2 and 3 shows the effect a change in tactic has on the actual routes taken during an attack. Figure 2 represents the rapid advance tactic, which requires rapid, straightforward movement to the objective. All five tanks chose a relatively straight route separate from one another. Figure 3 presents the routes chosen over the same terrain but using the bounding overwatch tactic. For this trial the platoon was divided in two sections, which is evident in the plot. Terrain is also used to minimize visibility and is reflected in routes that show a greater amount of aspect change and movement. Figures 4 and 5 are plots of the trails taken on the open terrain of Fort Bliss. Note that there is very little difference between tactics due to the limited amount of terrain cover available.

b. Tactical Approach Movement Sequence. Figure 6 is a time sequenced display of a bounding overwatch trial conducted on the Fort Knox East-West site. In this tactic the tank platoon is divided into a light and a heavy section of two and three tanks, respectively. As one section moved forward to a firing position, the other section would remain to provide covering fire. When the moving section reached a firing position, it would go into overwatch as the other section moved forward. Each section attempted to use terrain for maximum cover. This tactical movement is best displayed in a time sequenced trail plot such as figure 6. The x-axis represents the time sequencing of the trial while the y-axis is the range from a given defender to each target tank. The five tank paths begin at the extreme right, at time zero, at which point they were approximately 1,800 meters from the defender. During trial time as each tank moves toward the defender his range to that defender changes. This movement is reflected by the more jagged lines on the plot. If the tank has gone into overwatch at some time during the trial, its range to the defender remains constant until the tank begins movement again. This overwatch period is represented by the straight lines. In figure 6 the heavy section stayed in position for

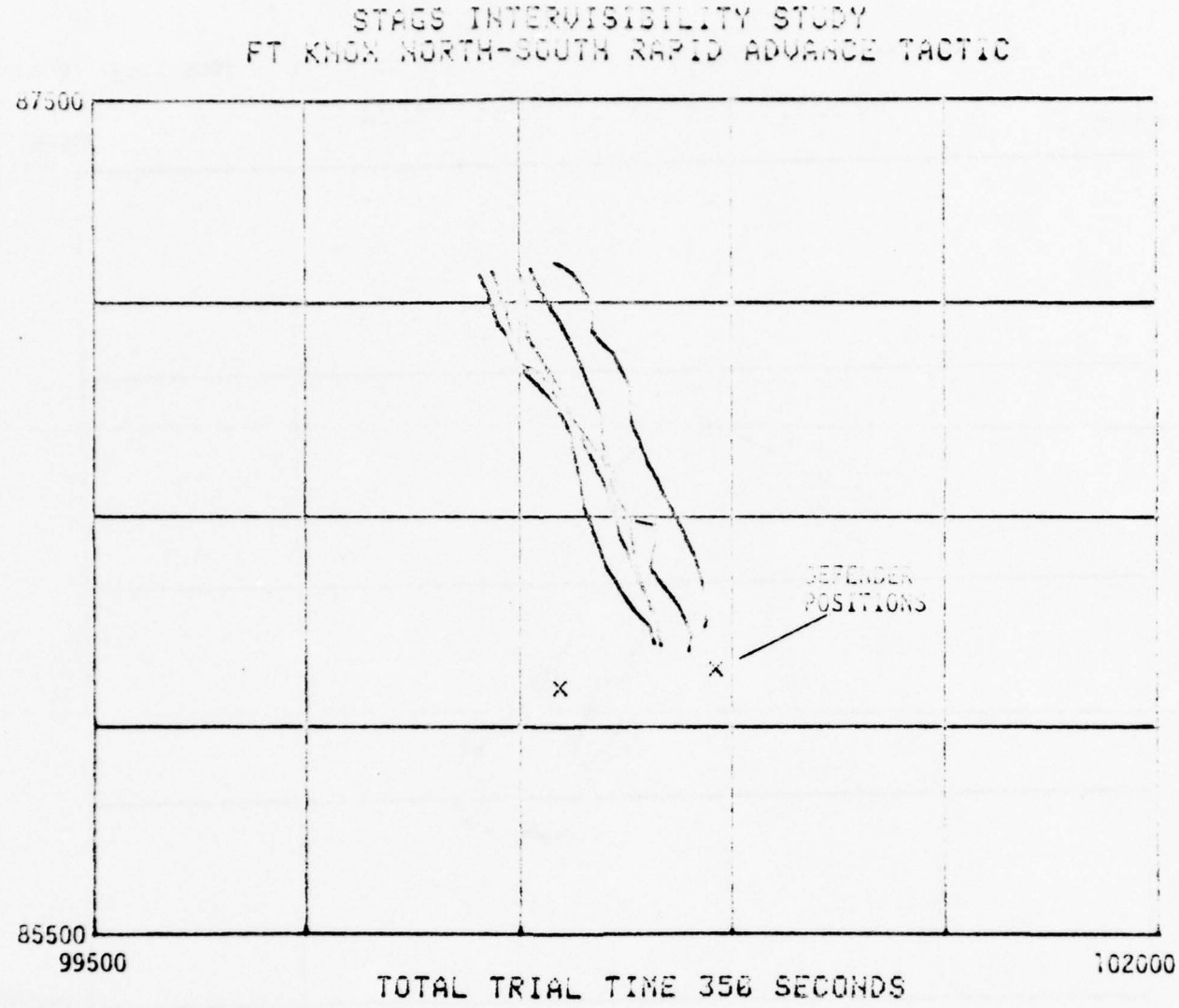

Figure 2. Fort Knox North-South site, trail plot rapid advance tactics

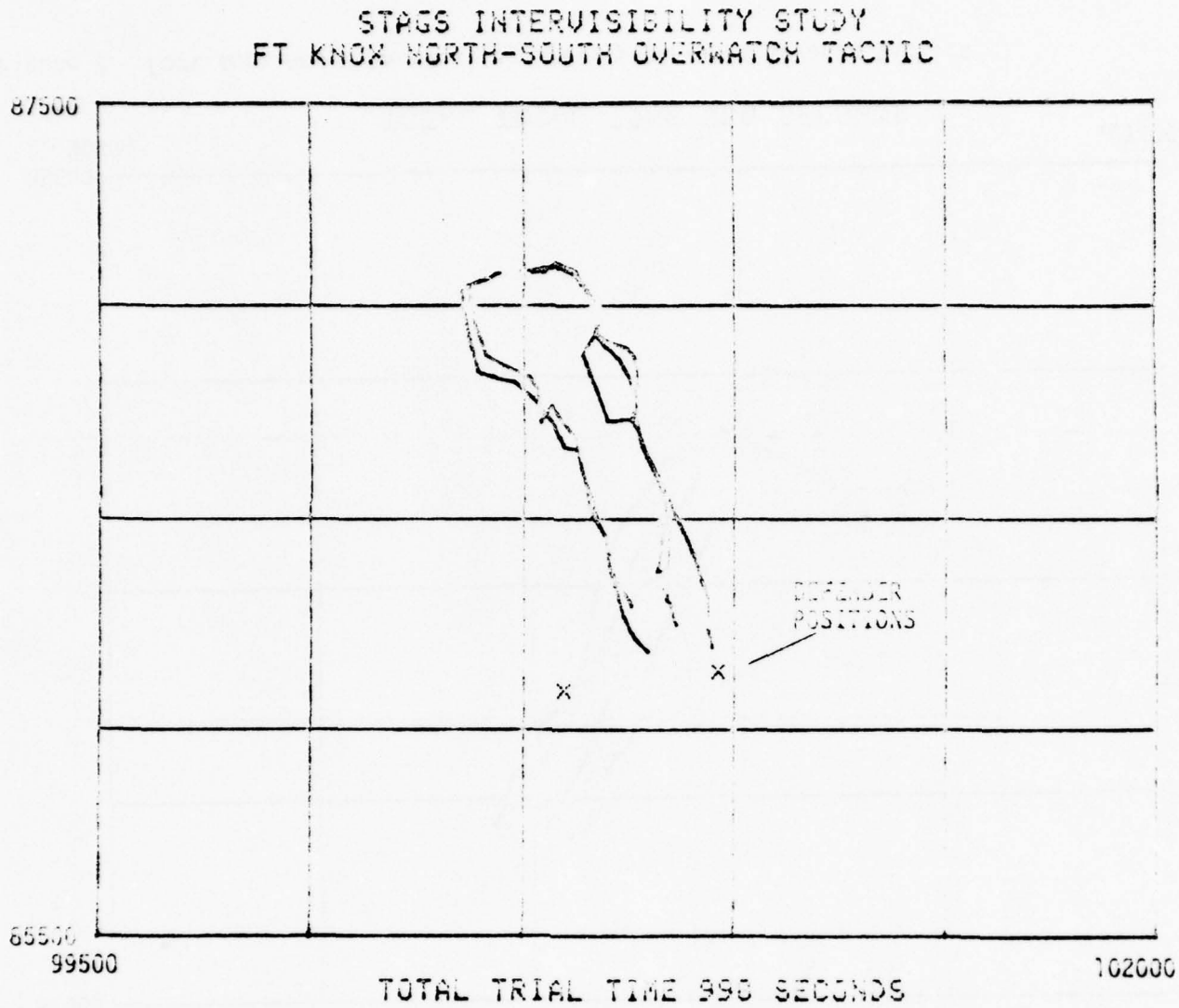

Figure 3. Fort Knox North-South site, trail plot, bounding overwatch tactics

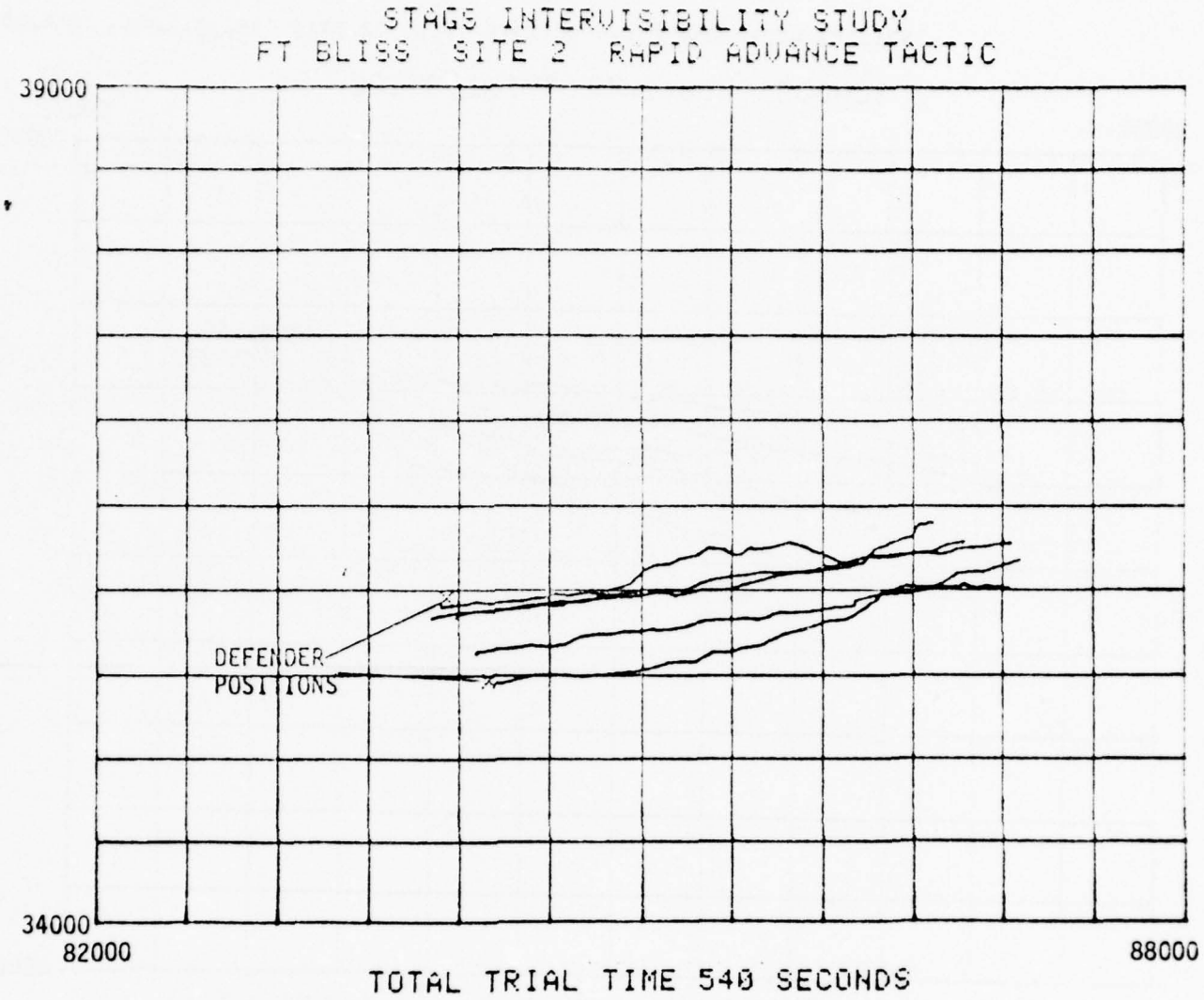

Figure 4. Fort Bliss, site 2, trail plot rapid advance tactics

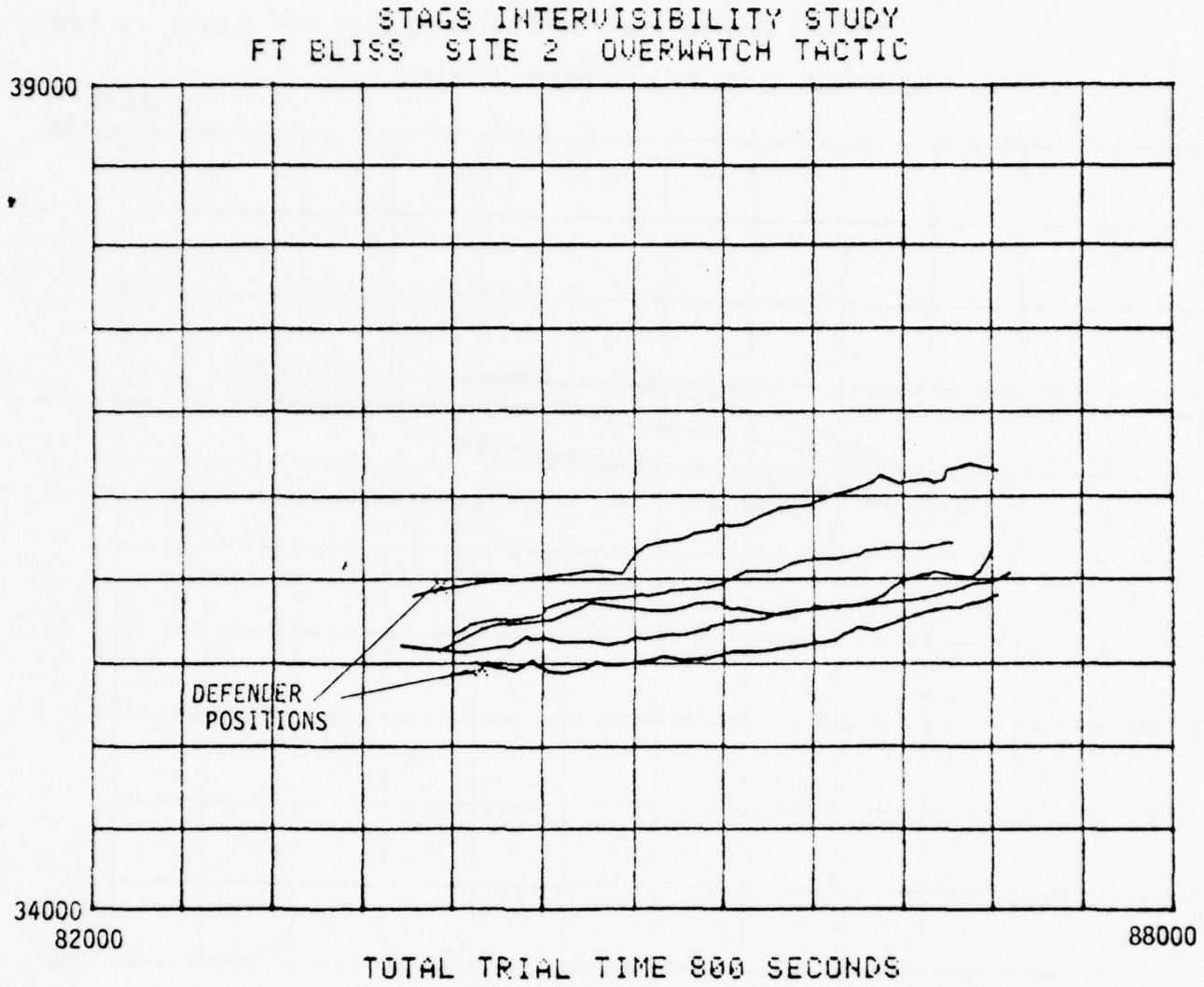

Figure 5. Fort Bliss, site 2, trail plot bounding overwatch tactics

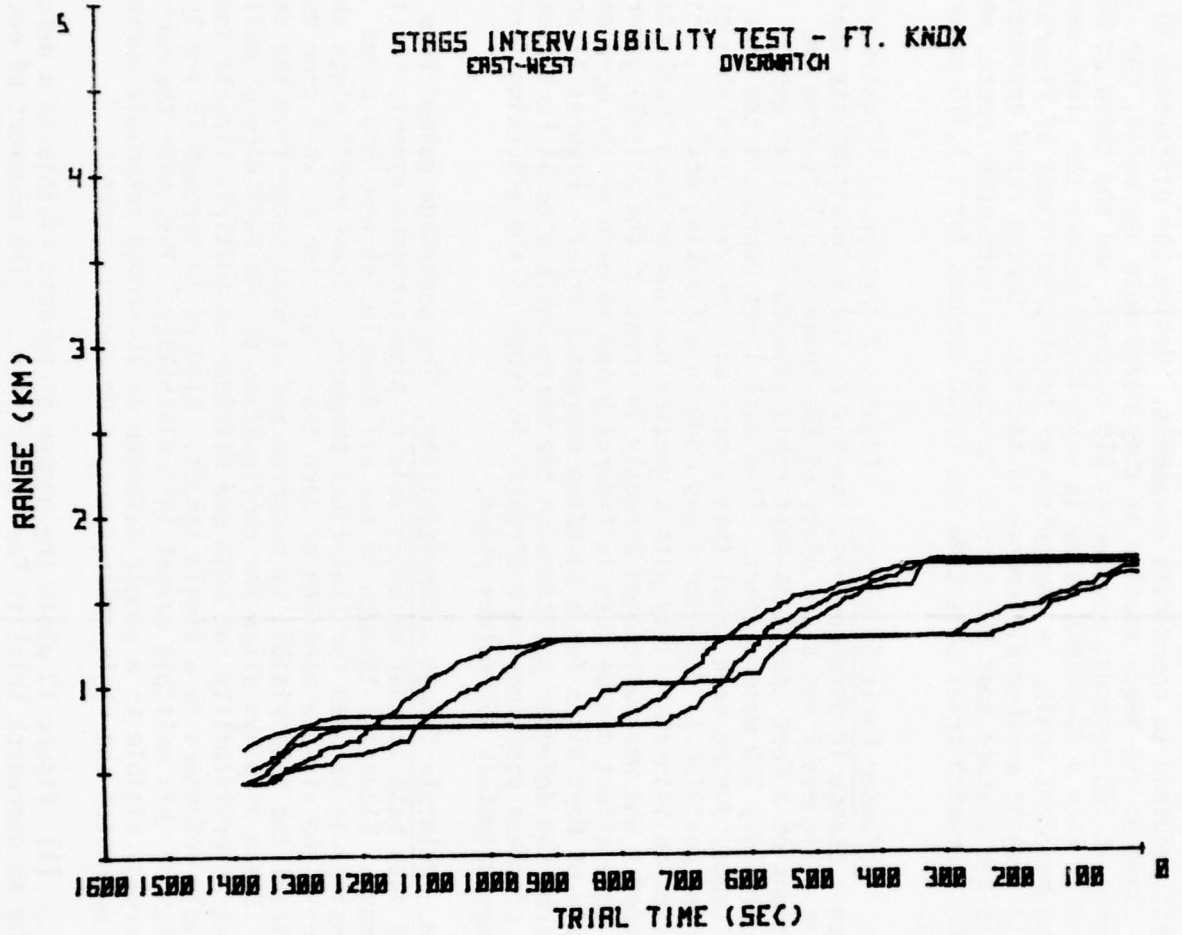

Figure 6. Time sequenced trail plot, Fort Knox East-West site

the first 300 seconds as the light section moved forward. For the next 500 seconds the light section remained stationary as the heavy section moved. At the 900-second mark the light section moved forward again. This plot illustrates the range versus time geometry involved in using this tactic and also the delay time experienced during communication efforts required to coordinate movements. Notice the difference in the halt times of the heavy section as they moved into overwatch; one stops movement at 720 seconds, another at 810 seconds, and the third at 880 seconds. Then a 30-second delay is experienced before the light section begins movement again. A comparison of total trial times of figures 7 and 12 reveals another difference in tactics. During rapid approach trials the platoon took 530 seconds to cover a 1,455-meter route, while in the overwatch trial this time was 1,390 seconds for a 1,475-meter route.

c. Defender Position Effects. Figures 7 through 12 illustrate the effect a change in defender position has on the intervisibility that occurs. Figures 7 and 8 are plots of the intervisibility from two positions of a Fort Knox East-West rapid advance trial that were approximately 270 meters apart. (The dark lines represent the time (and range) during each trial that a tank was intervisible with a given defender position.) Defender 1 was more in a flanking position, which resulted in intervisibility with a greater portion of each trail than defender 4 who was positioned directly in front of the attacking force. This same effect can be seen in figures 9 and 10 even on the more open terrain of Fort Bliss for a bounding overwatch trial. Figures 11 and 12 are from two defender positions on the North-South site at Fort Knox. Both of these positions were directly in front of the attacking force and approximately 450 meters apart.

d. Multiple Target Intervisibility. The advantage gained from the STAGS data base is that of being able to time sequence dynamic tactical movement. Figures 7 through 12 are all examples of how this added dimension can be used for analytical purposes. These trail plots show not only the visible portions of each trail but also at what time during the trial the intervisibility occurred and at what range from the defender. These displays allow for confirmation of the existence of multiple target intervisibility for both one defender on multiple targets and multiple defenders on a single target. Figures 13 through 16 are typical results of this multiple target intervisibility. They plot the number of targets visible to a single defender at 10-second intervals during both overwatch and rapid advance trials on various sites.

(1) Figure 13 plots the number of targets visible to a defender during an overwatch trial at Fort Bliss site 2. The movement of each section can be seen easily from this plot. For the first 350 seconds,

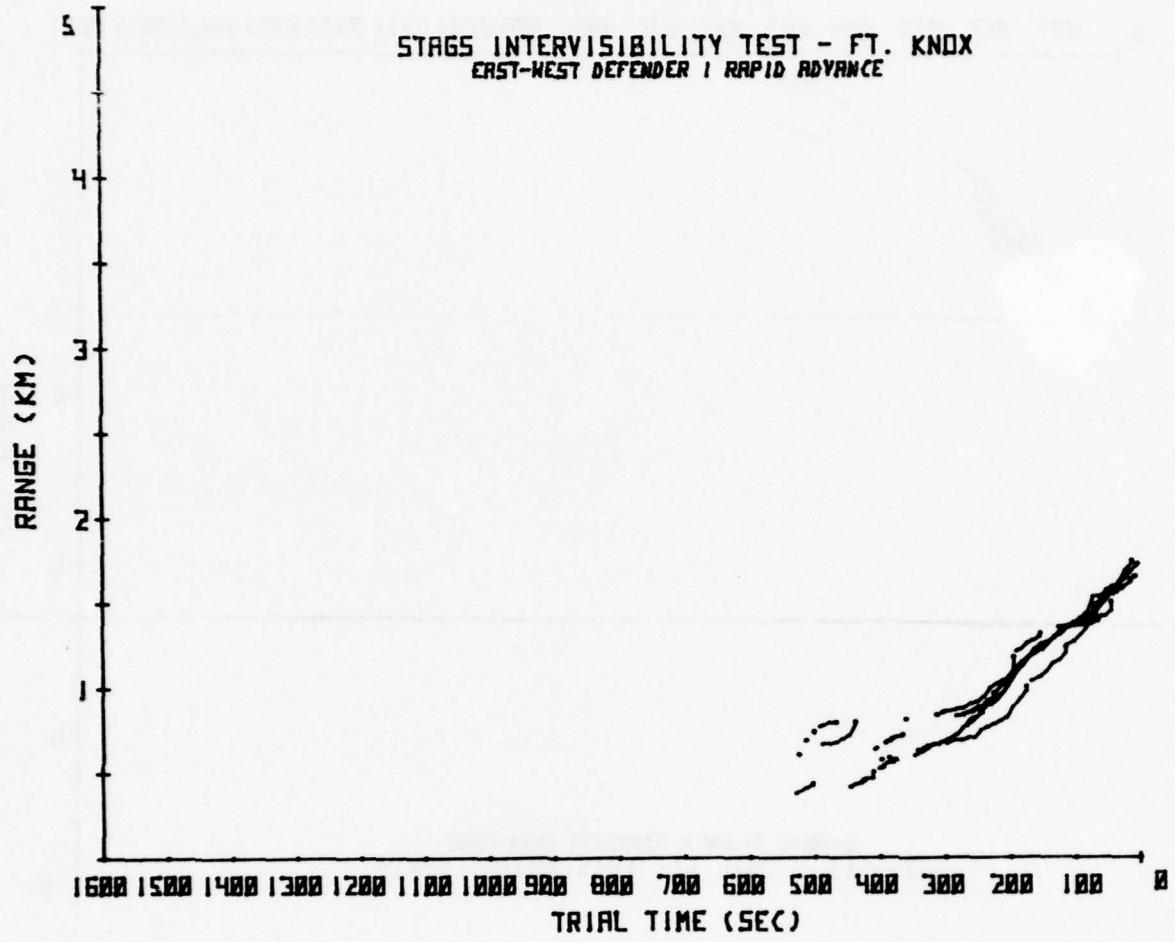

Figure 7. Example time sequenced intervisibility plot, Fort Knox East-West site, defender 1

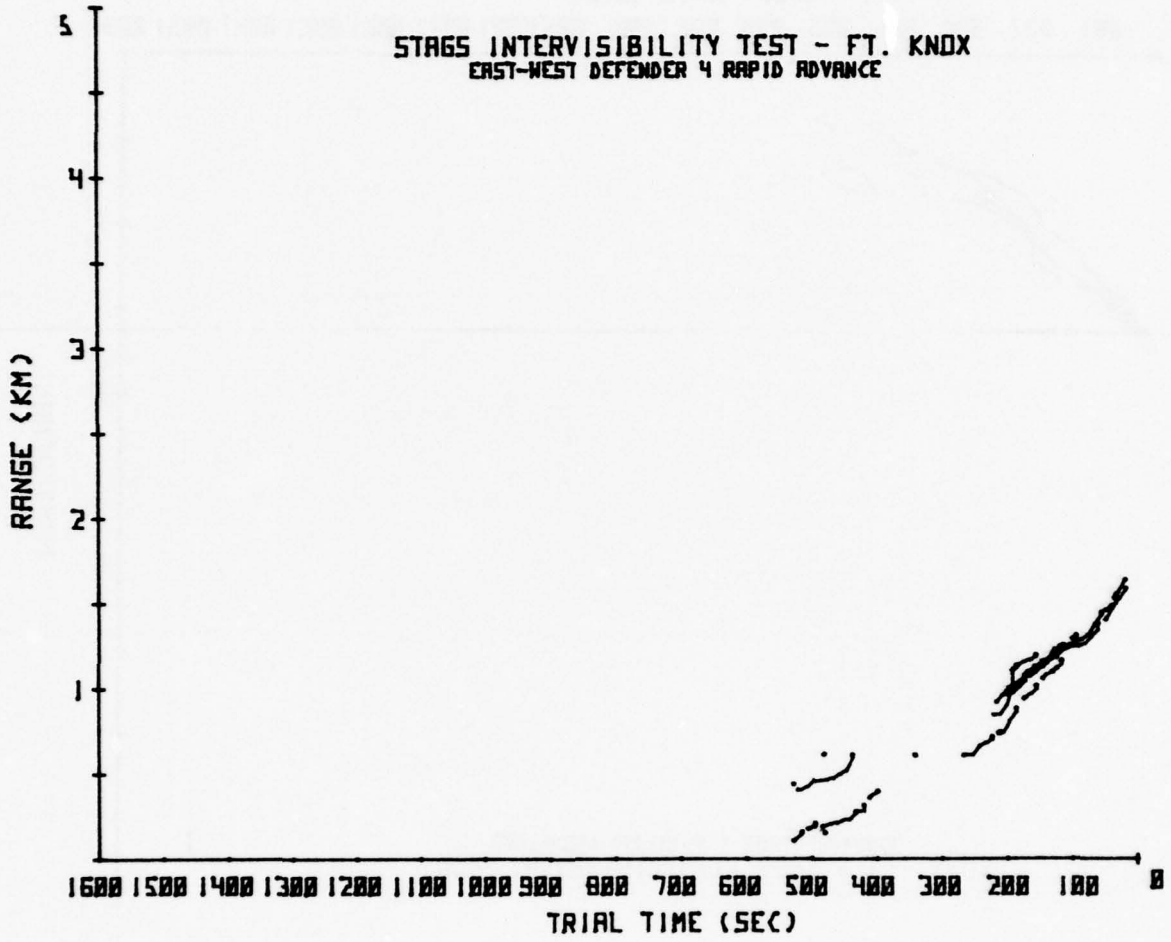

Figure 8. Example time sequenced intervisibility plot, Fort Knox East-West site, defender 4

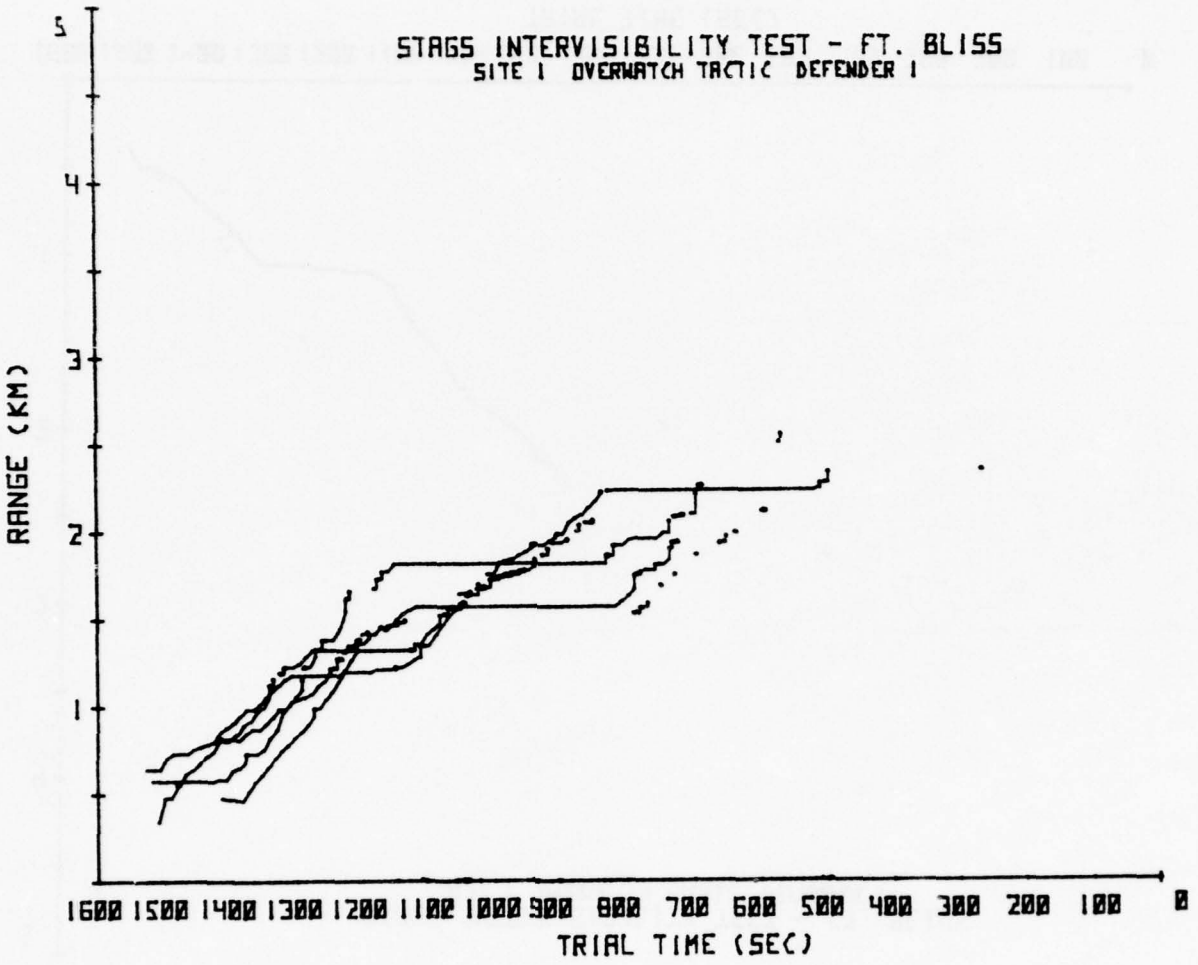

Figure 9. Example time sequenced intervisibility plot, Fort Bliss site 1, defender 1

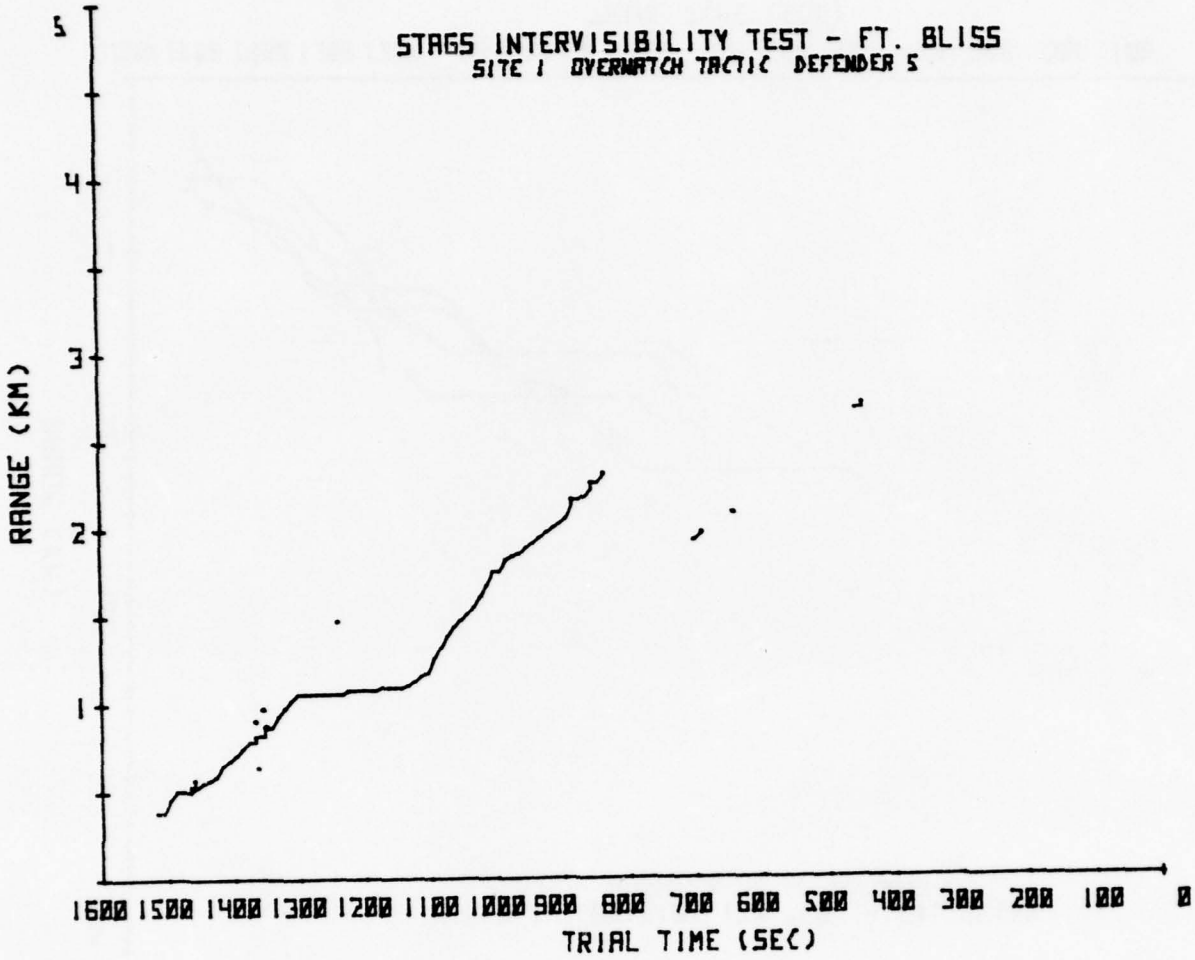

Figure 10. Example time sequenced intervisibility plot, Fort Bliss site 1, defender 5

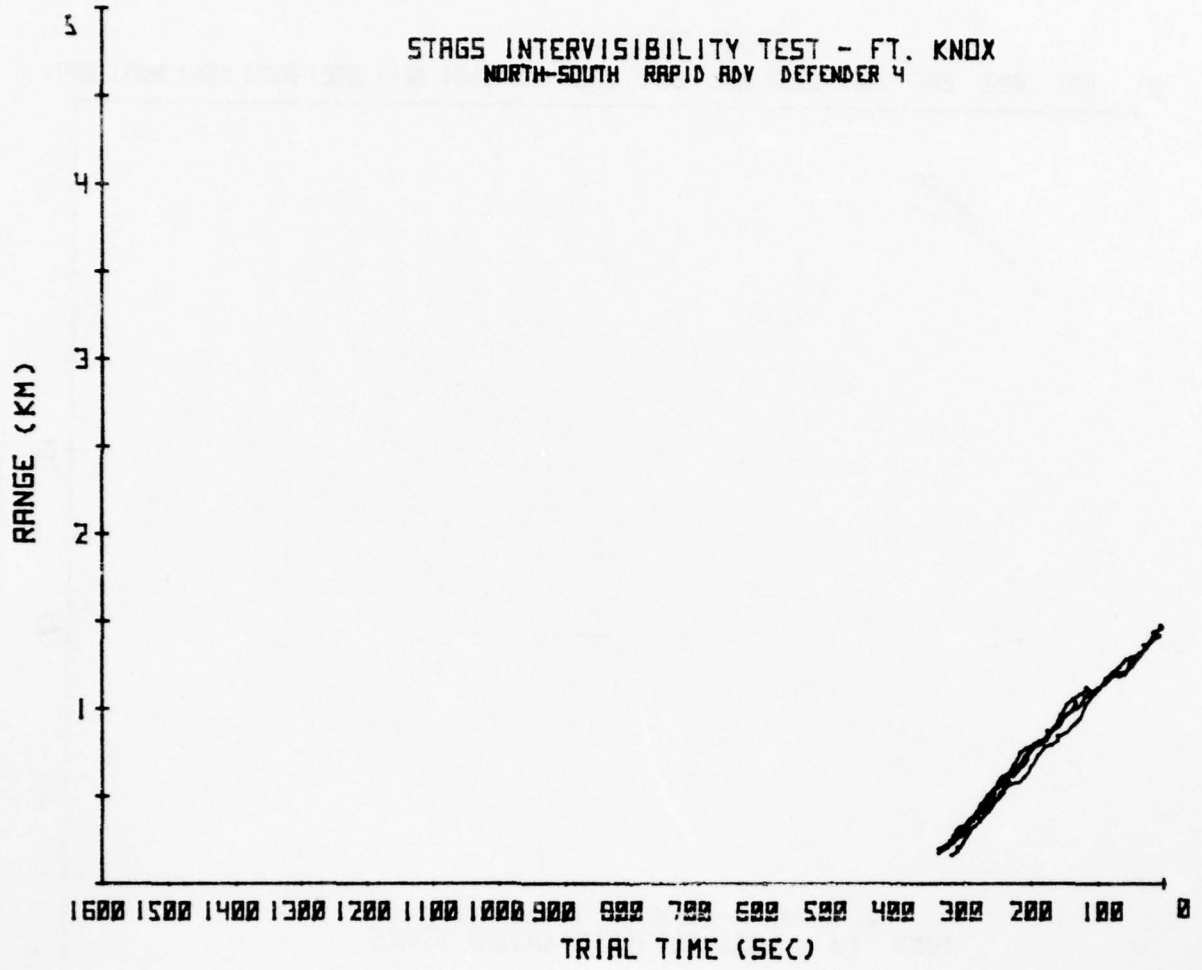

Figure 11. Example time sequenced intervisibility plot, Fort Knox North-South site, defender 4

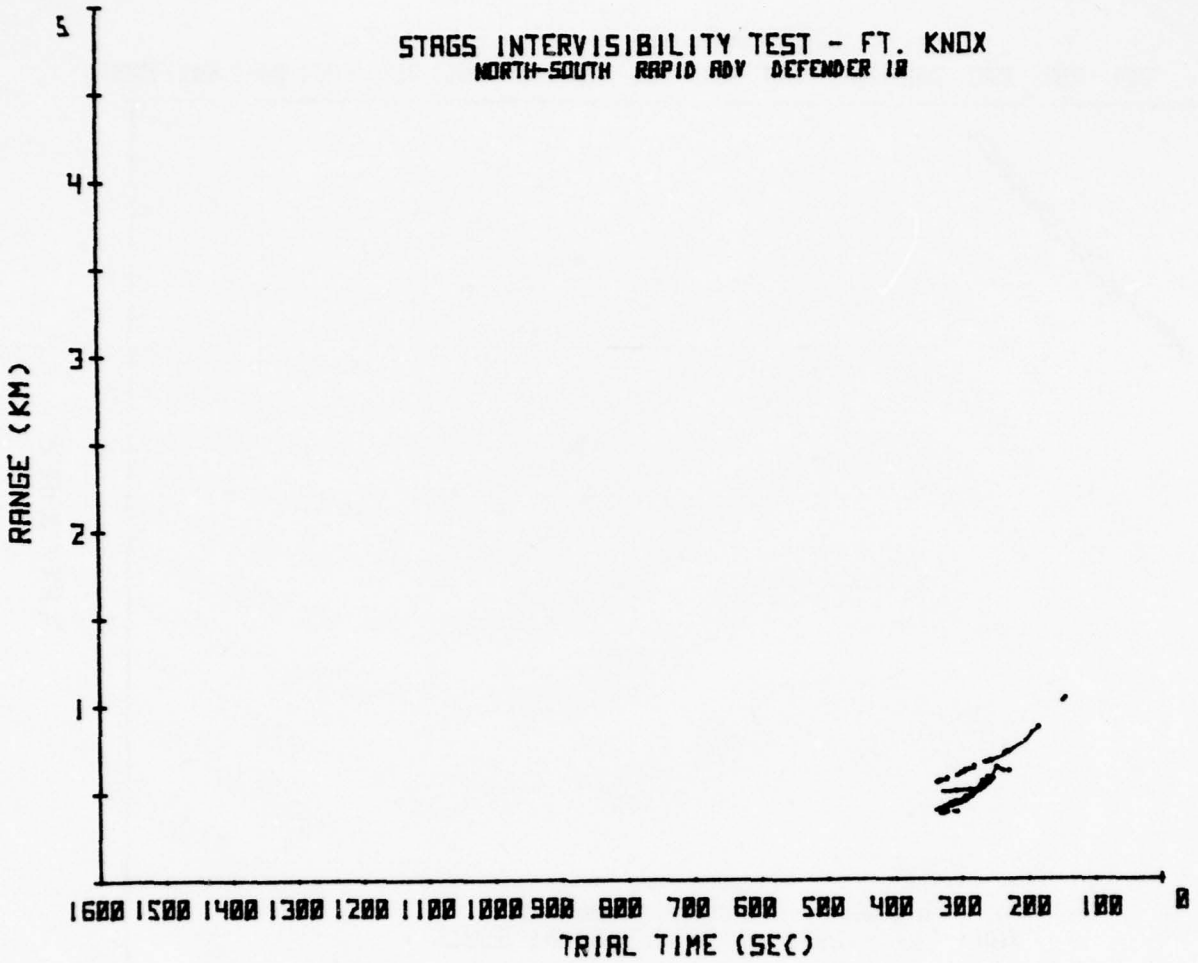

Figure 12. Example time sequenced intervisibility plot, Fort Knox North-South site, defender 10

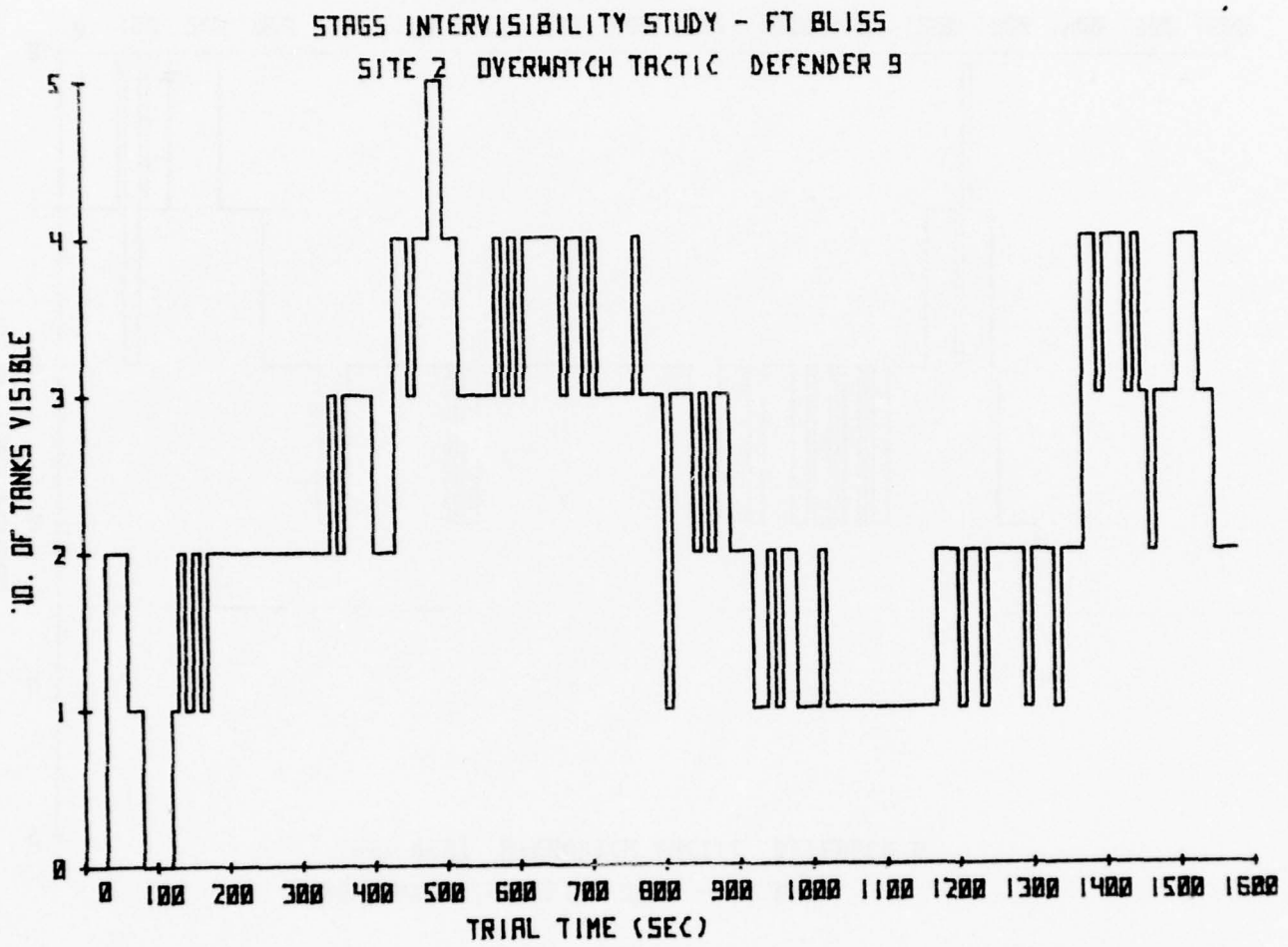

Figure 13. Example multiple target intervisibility, 1 observer/5 tanks, overwatch tactic

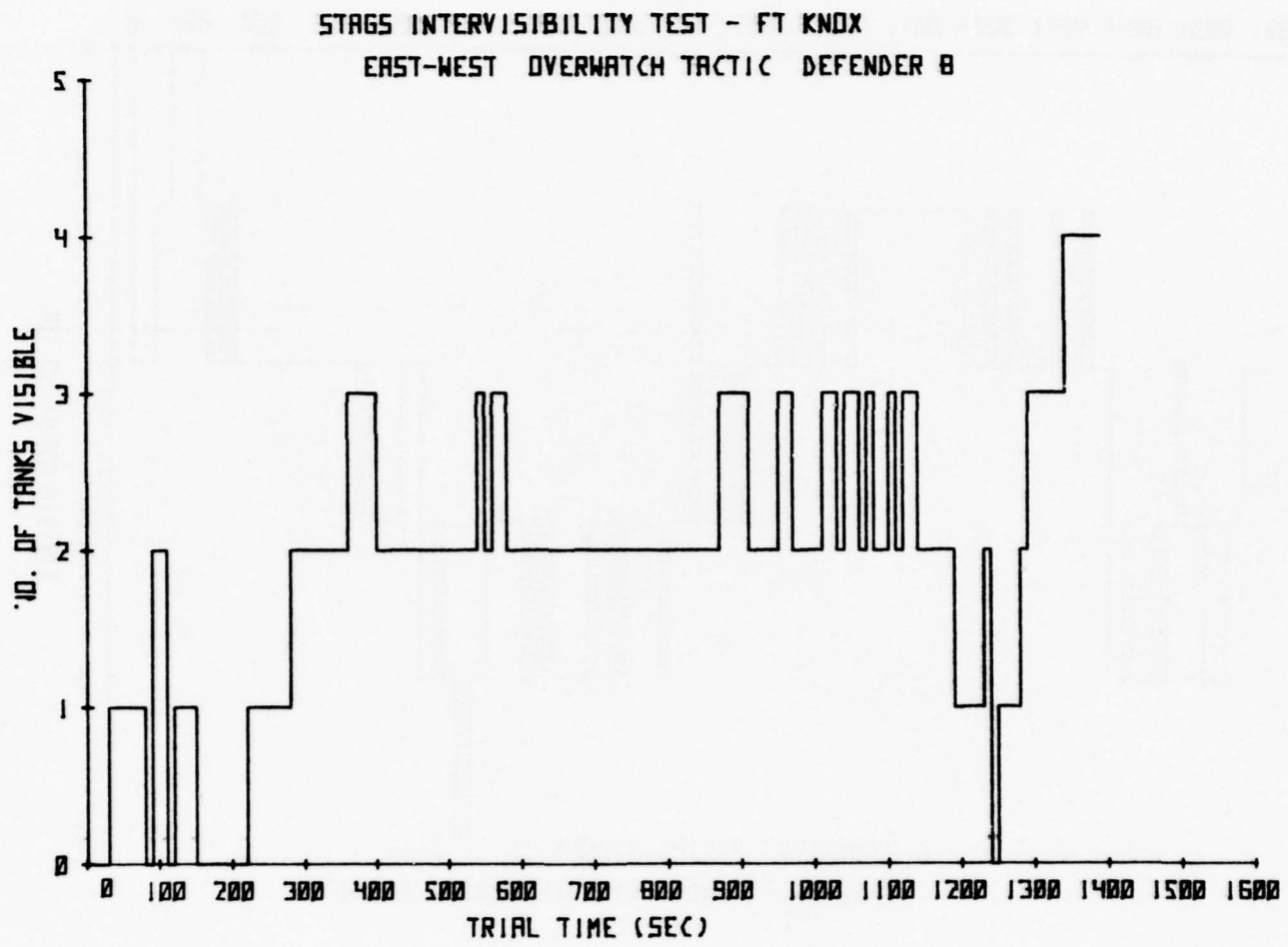

Figure 14. Example multiple target intervisibility, 1 observer/5 tanks, overwatch tactic

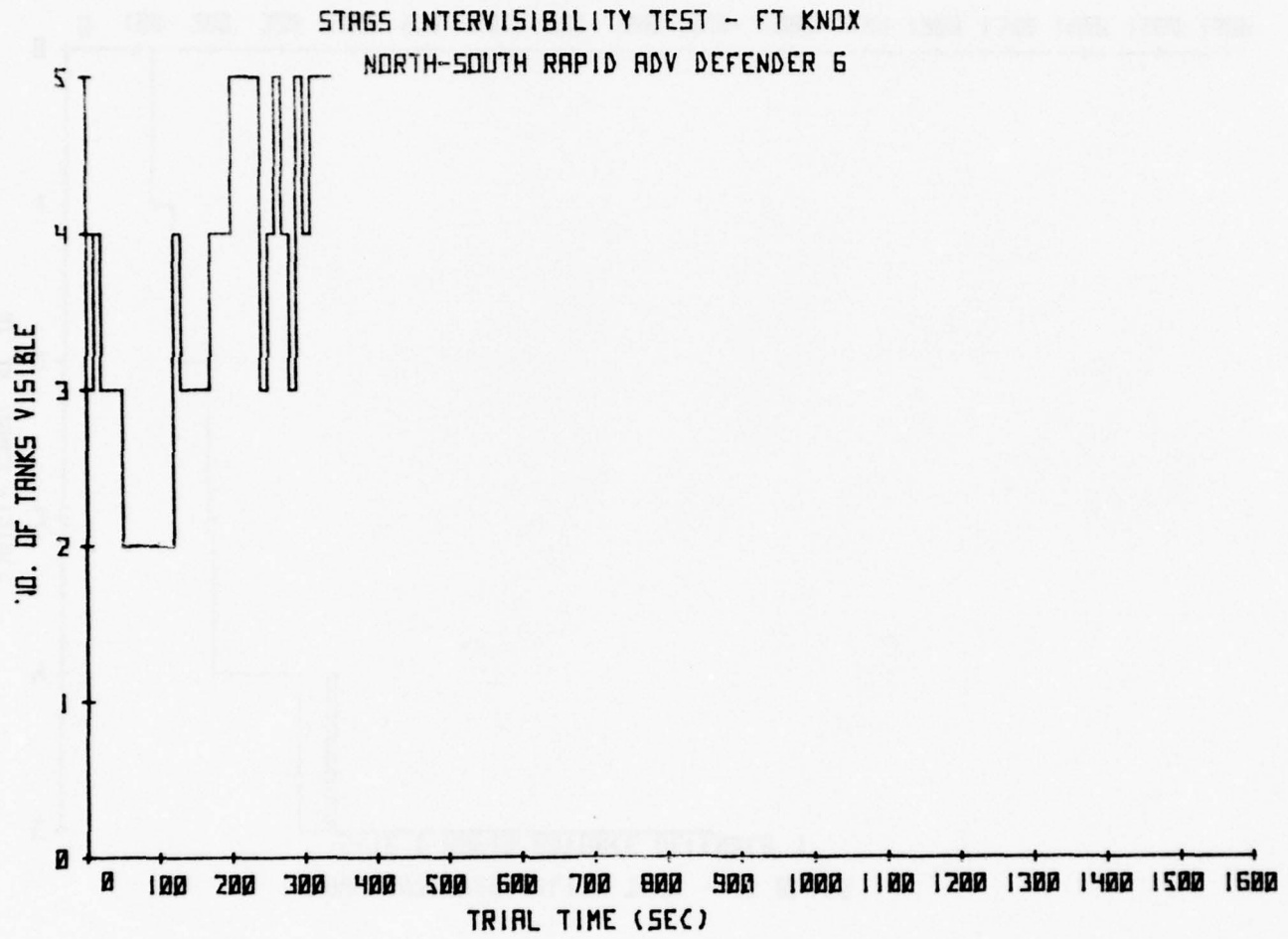

Figure 15. Example multiple target intervisibility, 1 observer/5 tanks, rapid advance tactic

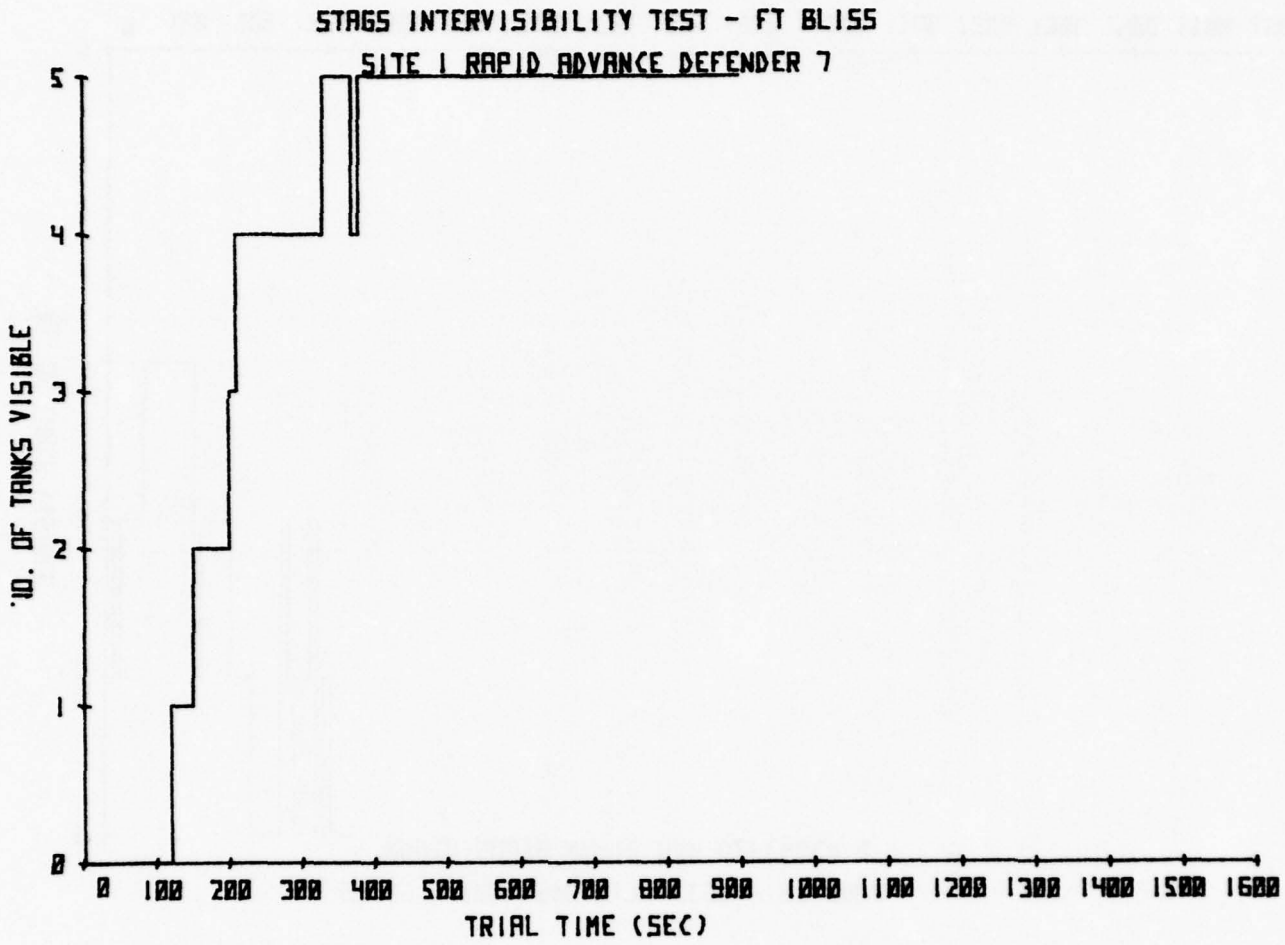

Figure 16. Example multiple target intervisibility, 1 observer/5 tanks, rapid advance tactic

only the light section is moving as only two targets are visible. When the heavy section begins movement, the number of tanks visible increases until they reach an overwatch position and the light section moves forward at the 900-second point. In figure 14 a similar result is noticed for a trial conducted on the wooded terrain of Fort Knox where only two tanks are visible for the first 200 seconds of the trial. Due to the terrain, better concealment was available when the light section went into overwatch so that for the next 1,000 seconds only the three tanks of the heavy section were visible to the defender. When this section goes into overwatch at the 1,100-second mark, the number of tanks visible drops again until 1,300 seconds when the entire platoon begins to move forward.

(2) Figures 15 and 16 show the difference in target visibility between the overwatch tactic of figures 13 and 14, which uses terrain cover to its maximum advantage, and the rapid advance tactic, which does not. Note the higher number of visible targets for a greater portion of trial time, regardless of the terrain over which the trial was conducted.

(3) Table 1 presents the average number of tanks that were visible to a given defender at any 10-second interval during the respective trial. Note the difference between tactic and terrain types. The rapid advance tactic consistently provides a greater number of visible targets to each defender regardless of the terrain over which the trial was run. A comparison of the figures from the Fort Knox terrain and those from the Fort Bliss terrain reestablishes that more targets will be visible on an open terrain than on a wooded area.

(4) Figures 17 through 20 are examples of other multiple intervisibility plots. (The dark lines represent only the time during each trial that a tank was intervisible with a given defender position.) Figure 17 is a plot of one defender's intervisibility with the five targets during a rapid advance trial at Fort Knox. Note the loss of LOS to all but one tank during a given period, suggesting a blocking terrain feature. Figure 18 plots the visibility existing between one tank and all defender positions for the same trial as figure 17. (Data were not available from positions 2 and 7.) The rapid advance tactic does not use terrain for cover during an attack. This is apparent here, for when the tank is visible to one defender, it is visible to all defenders. Figures 19 and 20 are examples of the visibility existing during an overwatch trial at Fort Bliss. Even though this tactic requires use of terrain features for cover, the open terrain of this site allowed for very little protection as can be seen by the extreme durations of visible segments.

Table 1. Average number of tank visible to given defender position (LOS taken at 10 second intervals)

Defender Number	FORT KNOX				FORT BLISS			
	EAST-WEST		NORTH-SOUTH		SITE 1		SITE 2	
	overwatch	rapid advance	overwatch	rapid advance	overwatch	rapid advance	overwatch	rapid advance
1	2.1	2.7	2.0	1.1	3.0	3.6	2.3	2.1
2	---	---	1.9	3.1	2.6	3.7	2.4	3.0
3	2.1	3	2.6	2.9	2.6	4.1	2.5	3.1
4	.8	1.5	2.2	3.7	3.2	.5	3.5	4.2
5	1.9	2.9	2.7	3.5	.5	3.4	3.5	3.7
6	1.6	2.8	1.8	3.6	3.0	3.9	3.4	3.7
7	---	---	1.5	2.5	2.9	3.7	2.5	2.4
8	1.9	3.5	1.8	2.3	3.3	4.0	2.3	2.5
9	1.8	2.7	1.0	1.2	4.9	5.0	3.3	3.8
10	2.7	3.0	.1	1.2	---	---	---	---
$\bar{x}$ =	1.8	2.8	1.8	2.5	2.9	3.5	2.9	3.2

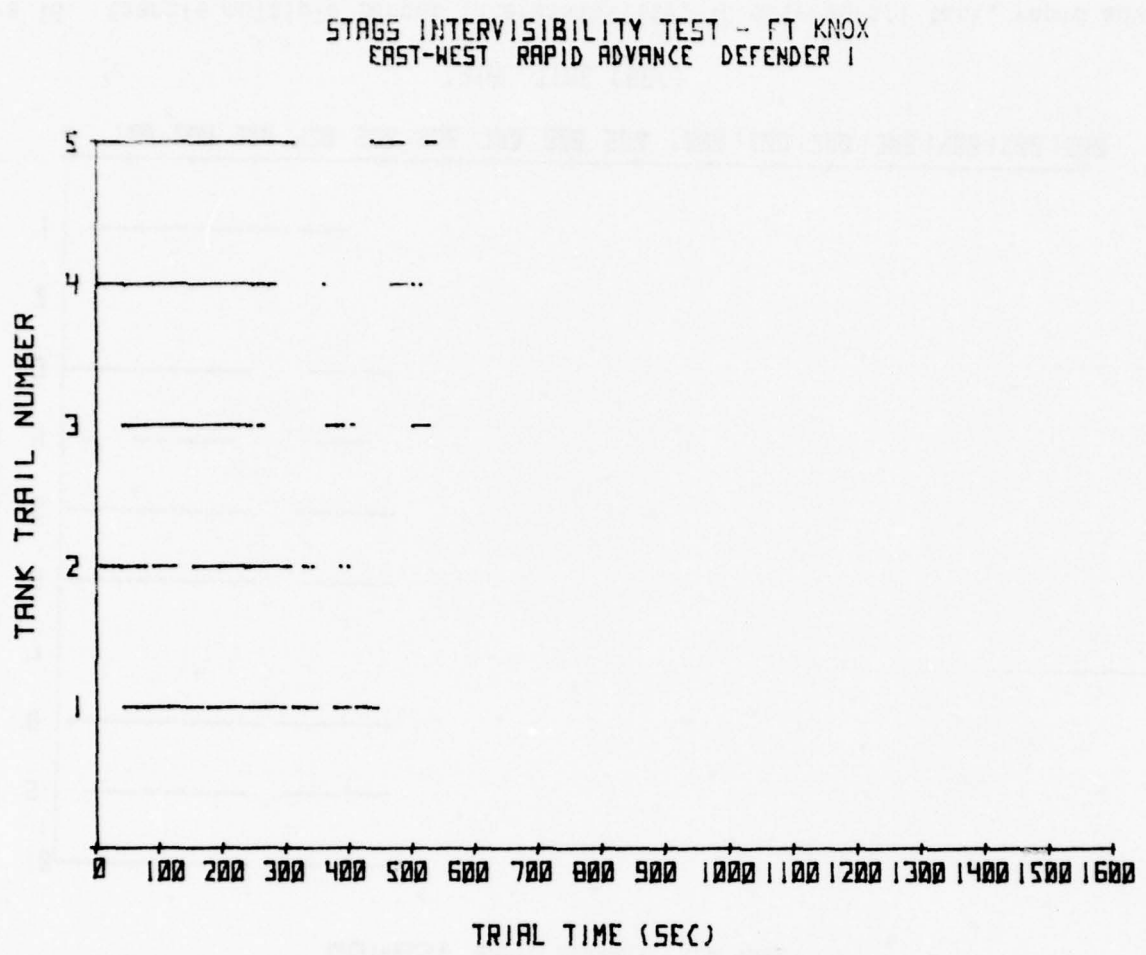

Figure 17. Example multiple target intervisibility, 1 observer/5 tanks, rapid advance

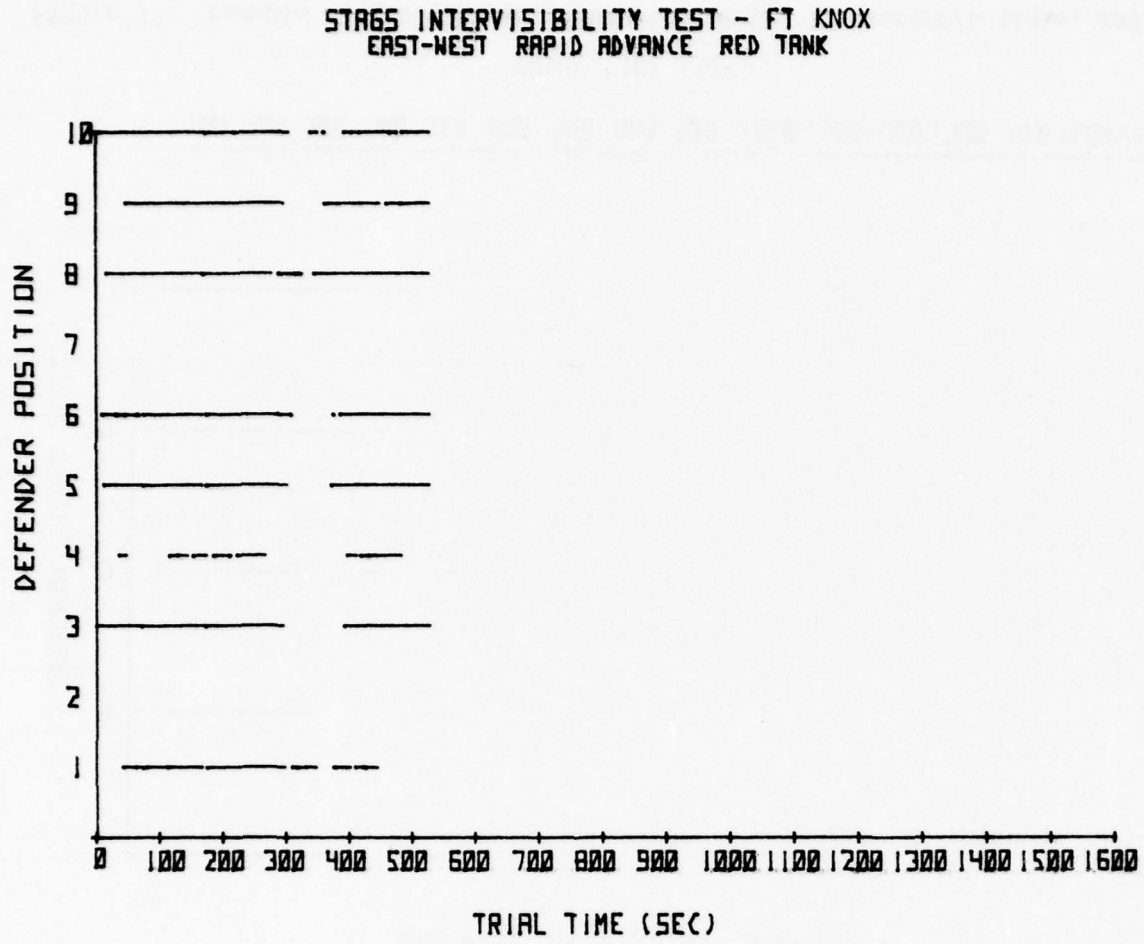

Figure 18. Example multiple target intervisibility, 10 observers/1 tank, rapid advance

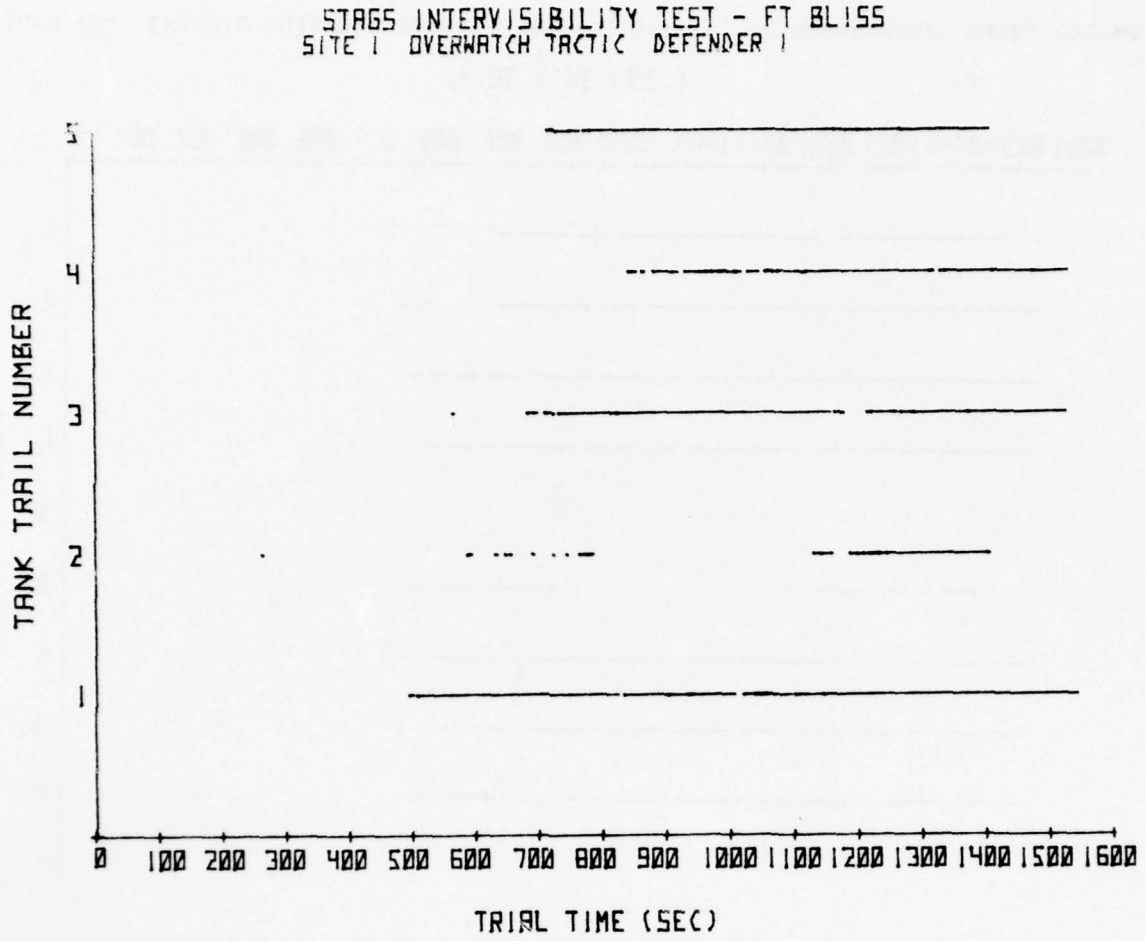

Figure 19. Example multiple target intervisibility, 1 observer/5 tanks, overwatch tactic

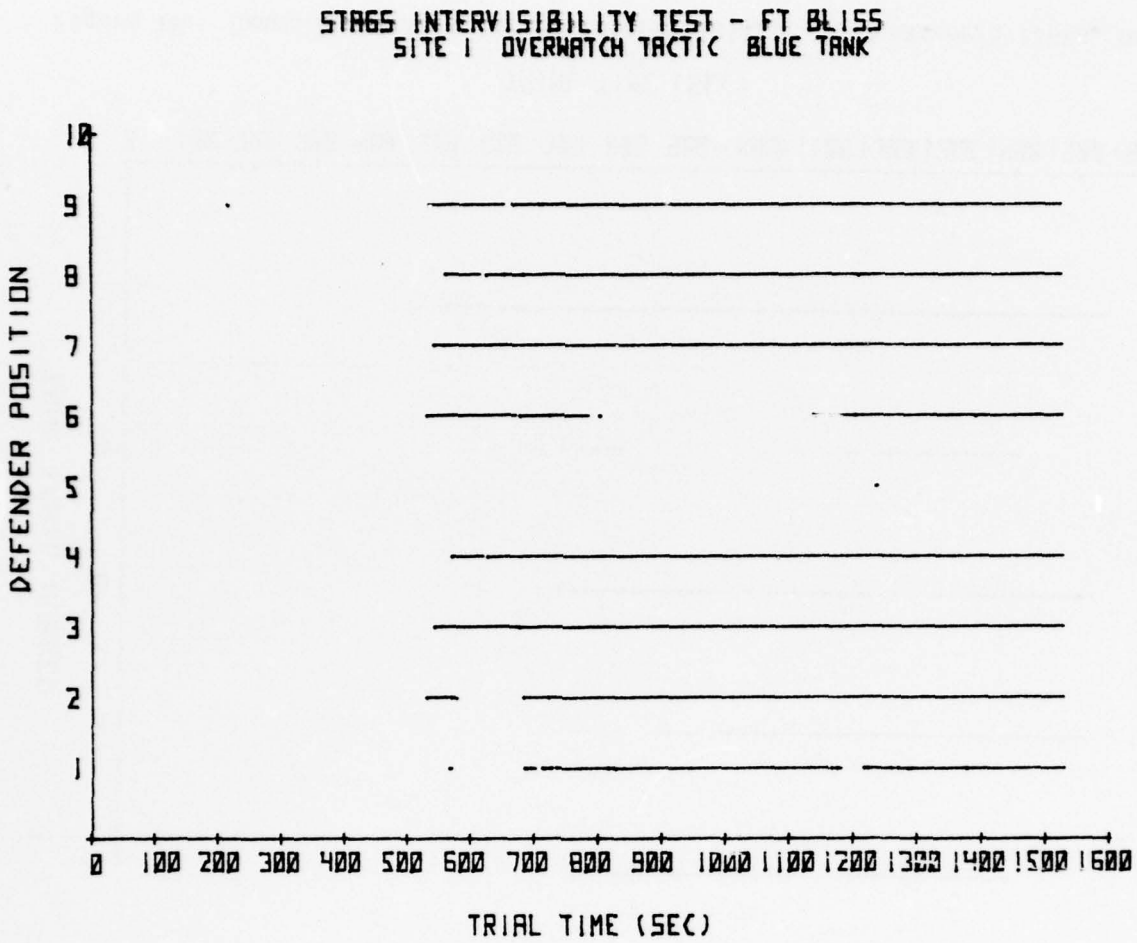

Figure 20. Example multiple target intervisibility, 10 observers/1 tank, overwatch tactic

e. Average Duration of Intervisible Times and Segment Lengths. Tables 2 and 3 present the average visible time segment and average visible segment lengths for each site and tactic. Notice the extreme difference between terrains, with the statistics for Fort Bliss more than double those of Fort Knox. Comparing tactics on similar terrain the average visible segment lengths and visibility times are relatively stable. As expected, the visible segment lengths in the overwatch tactic are less than those of the rapid advance trials due to increased use of terrain masking. The opposite trend occurs for the amount of time visible. This increase occurs in overwatch trials due to the

Table 2. Average visible segment length

Test Site	Tactics	Sample Size	Average Path Length (m)	Visible Segment Length (m) Mean	Std Dev
East-West	Rapid Advance	339	1455	118.9	194.4
	Overwatch	467	1475	47.5	69.2
North-South	Rapid Advance	323	1318	104.7	173.1
	Overwatch	393	1467	60.9	69.6
Site 1	Rapid Advance	253	2827	327.6	563.6
	Overwatch	390	3117	199.5	363.0
Site 2	Rapid Advance	370	4294	337.3	683.1
	Overwatch	376	4140	297.4	547.7

Table 3. Average visible time segment

Test Site	Tactics	Sample Size	Average Trial Time (sec)	Visible Time Segment (sec) Mean	Std Dev
East-West	Rapid Advance	340	530	36.4	57.6
	Overwatch	475	1390	43.3	131.0
North-South	Rapid Advance	325	340	25.8	44.3
	Overwatch	394	970	42.0	98.5
Site 1	Rapid Advance	255	760	83.1	147.7
	Overwatch	394	1500	87.6	179.9
Site 2	Rapid Advance	375	1040	76.1	155.4
	Overwatch	377	1580	101.1	221.2

increased opportunity for long periods of visibility while providing cover fire for the moving section. Caution should be exercised when comparing visible segment lengths with actual times of exposure. Longer segment lengths, like those at Fort Bliss, may not necessarily reflect the effect this measurement of LOS has on a defender's ability to track or engage the target. These longer segment lengths imply a more wide open terrain, which allows the attacking force to travel at increased speeds. An increase in attack speed will result in shorter LOS times, giving the defender a shorter time in which to track and successfully engage the target.

f. Opening Ranges. As stated in paragraph 4, the range between defender positions and attacking tanks did not exceed 2,000 meters at the Fort Knox sites and 4,500 meters at Fort Bliss. Table 4 lists the average defender to target range at first LOS initiation for each site. Comparing the two at each site, there does not appear to be any significant difference between opening ranges. This may be the result of both tactics being conducted on the same piece of terrain rather than any similarity of tactics. This appears plausible, since comparing the same two statistics for different terrain sites shows a wider variation.

Table 4. Range from defender to target at first LOS initiation (all defenders: 5 tanks)

		Mean (meters)
Knox East-West	Rapid Advance	1561
	Overwatch	1366
Knox North-South	Rapid Advance	1207
	Overwatch	1283
Bliss Site 1	Rapid Advance	2371*
	Overwatch	2489
Bliss Site 2	Rapid Advance	3686
	Overwatch	3842

* Data available for three tank paths only.

g. Velocity Profiles. Figures 21 and 22 are cumulative plots of the velocity profiles for the five tanks during a rapid advance trial at each 10-second block increment for the Fort Knox East-West site and site 2 at Fort Bliss. The effects of terrain are quite noticeable here. Whereas in both trials the rapid advance tactic was used, the rougher, more wooded terrain of Fort Knox slowed down the attack considerably. At Fort Knox 80 percent of the velocities were less than 4m/sec, while on the more open terrain of Fort Bliss, 80 percent of the velocities were 5.5m/sec or less. It is also important to note the great range in velocities for both sites, implying that velocities are not constant over a given area but depend on the terrain encountered

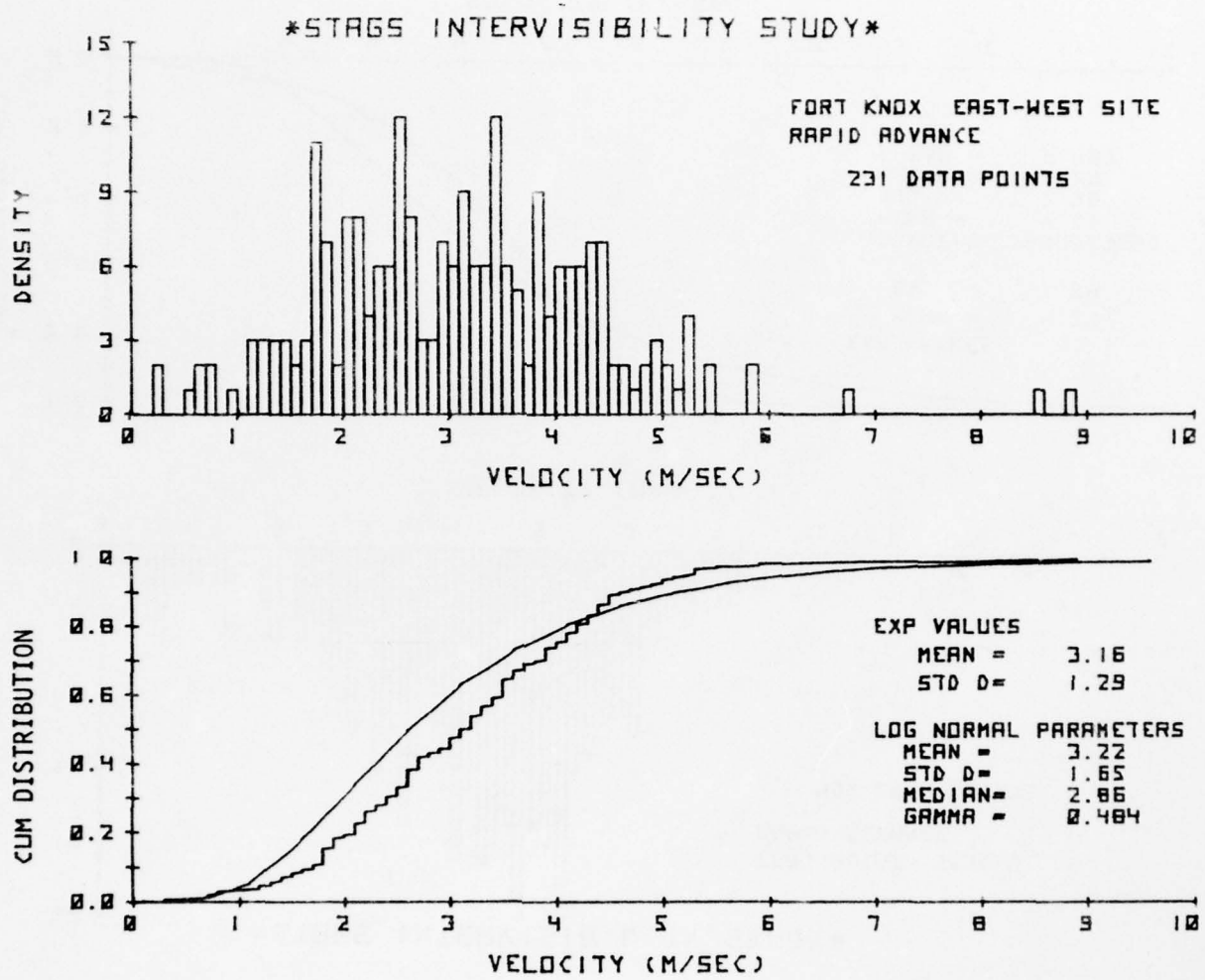

Figure 21. Velocity profile Fort Knox East-West site rapid advance tactic

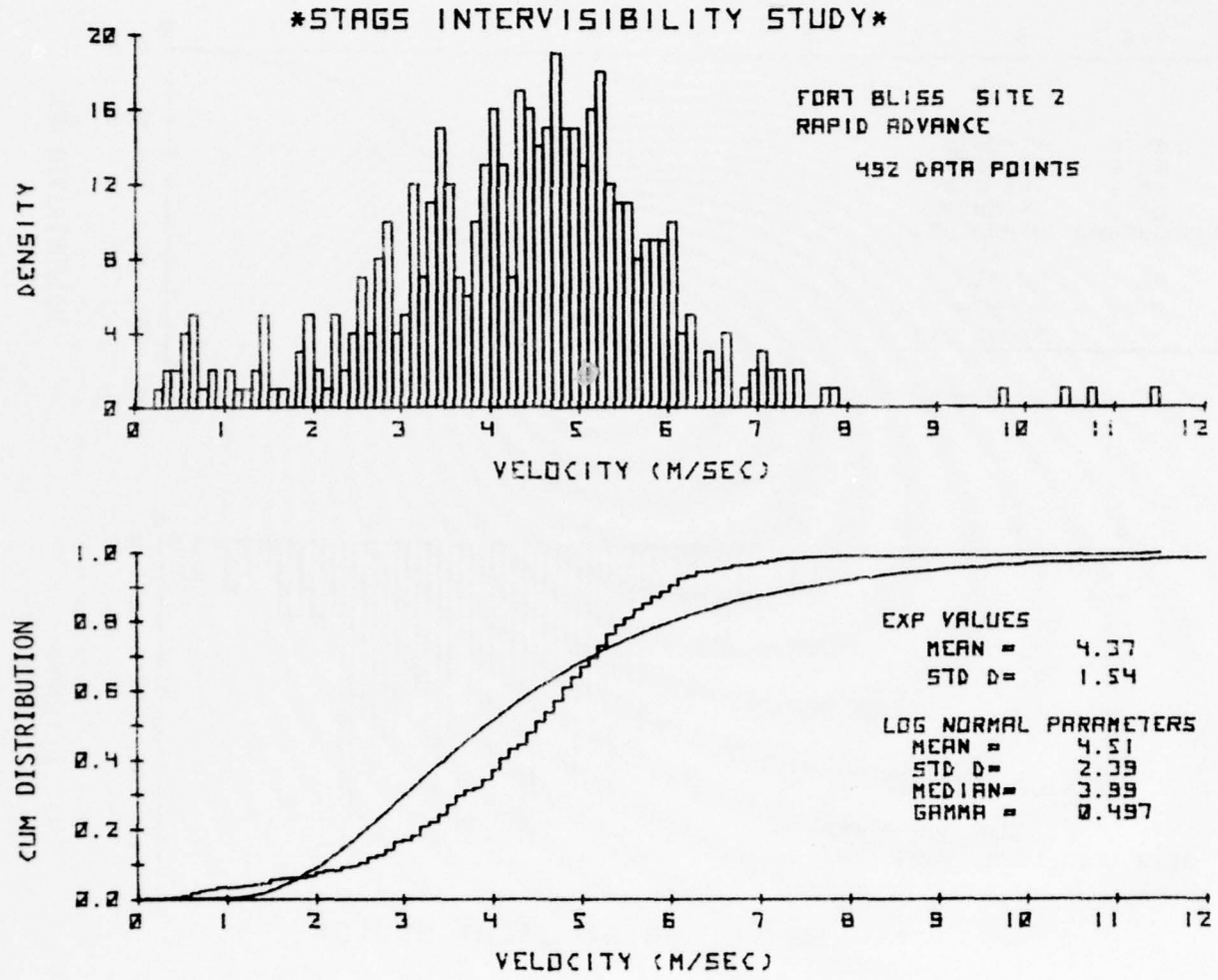

Figure 22. Velocity profile Fort Bliss site 2 rapid advance tactic

from moment to moment during an attack. Table 5 gives the average velocity for each tactic on each trial site. From these data it can be seen that velocity is dependent not only on the terrain over which the attack occurs but also on the tactic used. The overwatch tactic in which the attacking force is to use terrain to its maximum advantage has the effect of not only increasing trial time but also slowing down the overall advancing velocity of the attack.

Table 5. Average advance rates (m/sec)

Site	Tactic	Mean	Std Dev
Knox East-West	Rapid Advance	3.16	1.29
	Overwatch	2.40	1.22
Knox North-South	Rapid Advance	3.88	1.23
	Overwatch	2.80	1.37
Bliss Site 1	Rapid Advance	4.22	1.68
	Overwatch	3.75	1.42
Bliss Site 2	Rapid Advance	4.37	1.54
	Overwatch	4.33	1.36

h. Laser Intervisibility Analysis. During the second phase of each trial intervisibility data were also collected using a laser source and laser receivers. An omnidirectional laser was mounted on the gun of the tank as it retraced the attack paths. Laser receivers were placed at five of the ten defender positions. These receivers provided continuous tracking of the intervisibility status of the laser source with a 17 degree cone of track. The position of the laser source provided intervisibility status disregarding low ground cover but did not account for instances of high canopy cover such as that caused by trees where the lower part of the tank could remain visible. The use of a single laser source results in LOS measurement only to that point on the tank. Thus, parts of the tank could be visible to an observer but at the same time be considered out of LOS to the laser receiver.

(1) The laser intervisibility data have small breaks in LOS caused by trees, branches, or tops of dunes. These small breaks can be ignored for very fast time of flight systems. For some of the newer systems developed and under development, small clutter can effect system performance greatly. Systems that are constantly transmitting guidance information, such as the TOW or laser beam rider, cannot have clutter between the missile and the tracker while the missile is in flight. Vegetation that is local to the firer would be the primary problem for this type of system.

(2) The masking that is local to the target could have greatest effect on two types of systems. These would be the system employing

seekers and the systems with warheads that cannot penetrate clutter without detonating. The seeker systems, spot lasers, thermal imaging, and optical contrast must have continuous lock-on to the target until missile impact. Small clutter can greatly affect the lock-on of these systems. The density of the masking and the sensitivity of the warheads will determine how the clutter would affect a missile's ability to penetrate clutter. The density of masking was not measured in this test.

(3) This test did not collect data on the location of the interrupting features. However, a majority of the masking in the heavily vegetated terrain of Fort Knox probably occurred close to the target since the observer positions were elevated above the approach trails and the threat vehicles had a large amount of vegetation to use for cover. The Fort Bliss observers did not have the elevation advantage that existed at Fort Knox nor did the threat force have much vegetation for cover. Masking at Fort Bliss was mainly caused by sand dunes, and these were not necessarily local to the threat vehicle.

(4) The differences in exposure times recorded by the five observers and corresponding laser receivers for a given platoon approach are shown in table 6. The differences in the sample sizes reemphasize the increased breaks in LOS detected by the lasers and not by the observers. Also provided in this table are the values of exposure times calculated if LOS breaks less than 2 and 5 seconds are ignored in the laser data. Filtering the data in this manner shows how many of the breaks in LOS are due to small clutter in the terrain. A 2-second filter on the laser data at Fort Knox results in average exposure times that are approximately equal to the average times recorded by the observers. This is based on the fact that the average velocities during Fort Knox trials were approximately 3 meters per second. The 2-second filter would thus give the effective intervisibility to a 6-meter target rather than a single point source.

(a) Fort Knox East-West site. This site was located on the Saint Vith Tank Range at Fort Knox, Kentucky. The terrain was rolling with heavy vegetation and large patches of open area. The defender positions were on a hill sloped up to 20 to 30 meters above the start point of the tank approaches. The approach was limited to specific points at two or three areas in the site due to streams crossing through the range.

1. Comparing the observer and laser mean exposure times and sample size emphasizes how the vegetation found in the area affected the measurements. A 2-second filter on the laser data recorded during the rapid advance trial brings the average time of intervisibility into closer agreement with the observer data. For the overwatch trials

Table 6. Observer and laser exposure times (seconds)

Site	Tactic	Observer Data Mean	Observer Data Std Dev	Observer Data No.	Laser Data Mean	Laser Data Std Dev	Laser Data No.	Filtered Laser Data 2 second Mean	Filtered Laser Data 2 second Std Dev	Filtered Laser Data 2 second No.	Filtered Laser Data 5 second Mean	Filtered Laser Data 5 second Std Dev	Filtered Laser Data 5 second No.
Fort Knox													
East-West	Rapid Adv	33.86	51.82	223	7.56	23.67	1002	29.79	56.59	263	58.73	80.67	140
	Overwatch	40.17	124.02	290	8.46	49.79	1303	23.68	80.82	493	45.59	113.73	272
North-South	Rapid Adv	24.75	41.75	149	4.82	15.85	395	15.88	34.22	129	28.24	43.98	78
	Overwatch	36.68	91.05	182	11.28	53.49	598	28.45	85.75	246	44.70	104.67	162
Fort Bliss													
Site 1	Rapid Adv	79.95	146.18	164	53.79	163.33	280	145.93	265.07	104	206.67	296.26	74
	Overwatch	68.04	154.63	315	71.39	230.63	375	171.48	362.96	157	268.54	449.04	104
Site 2	Rapid Adv	59.09	114.43	251	16.63	57.97	862	53.56	122.32	275	87.99	160.67	171
	Overwatch	76.10	187.47	262	27.50	98.56	797	78.99	205.88	282	138.91	276.00	163

a 5-second filter on the laser data brings it into closer agreement with that of the observer.

2. This indicates that for the rapid approach tactic, where the tank is constantly moving, the breaks in LOS that were detected by the laser receiver but not by the observer were breaks of less than a tank length. However, for the bounding overwatch tactic, where the tank is able to stop and start in covered positions, the observer is forced to make more judgments on the tank's LOS status. The reliance on the individuals judgment and the difference in definitions of intervisibility for laser and observer appear in the data as approximately 5 seconds of exposure time.

(b) Fort Knox North-South site. The North-South site overlapped part of the East-West site. The site was more level and the middle of the terrain was very open with dense woods on both sides. The observer positions were not more than 5 meters above the approach area. The vegetation was of a denser nature, such as evergreens, than that found on the East-West site. The exposure data show less small, choppy clutter but, on the other hand, the breaks in LOS were much longer when they occurred. The filtering of the laser data does bring them into very close agreement with the observer results. The mean observer exposure time falls between the 2- and 5-second filtered laser data. It would appear that more observer judgment was required during the rapid approach trial and less in the overwatch trial than occurred in the East-West site trial.

(c) Fort Bliss. The experiment at Fort Bliss was conducted in clear, windy weather. The tank trails were more than double the distances available at Fort Knox. Both observations in the field and the resultant data indicated that perception of the tank at ranges exceeding 3,500 meters was a problem. Even with a slight dust trail following the tank it was difficult for the observers to say positively that the tank was in LOS at these long ranges. Table 7, average total exposure times, confirms these observations. The average total exposure times recorded by the laser receivers at Fort Bliss were greater than those times recorded by the observers in all but one case (rapid advance at site 2).

1. Site 1 had gently rolling terrain with dunes varying from 1 to 3 meters in height. The area in which the observer positions were located gently sloped to approximately 5 to 10 meters above the approach area. Intervisibility on this site was broken mainly by the rolling terrain as opposed to sand dunes. Since LOS breaks were caused by land forms, the laser and observer data are in closest agreement on this site.

Table 7. Average total exposure time (seconds) (per position per tank)

Site	Tactic	Observer	Laser	Filtered Laser Data 2 second	Filtered Laser Data 5 second
Fort Knox					
East-West	Rapid Adv	302.03	303.00	313.39	328.89
	Overwatch	465.97	440.74	466.97	496.02
North-South	Rapid Adv	147.51	76.16	81.94	88.11
	Overwatch	267.03	269.82	279.95	289.66
Fort Bliss					
Site 1	Rapid Adv	524.47	602.45	607.07	611.74
	Overwatch	857.30	1070.85	1076.89	1117.13
Site 2	Rapid Adv	593.26	573.40	589.16	601.85
	Overwatch	802.77	876.70	891.01	905.69

2. Site 2 was on an area where the dunes were 2 to 3 meters high throughout the entire site. The tanks were required to maneuver sharply to go around the closely spaced dunes. There was choppier LOS due to these dunes than at site 1. Due to the higher velocities at Fort Bliss, many of these interruptions were tracked through by the observers. Cover to be used in the overwatch trials was difficult to find. The observer data for the overwatch trial closely agree with the 2-second filtered laser data. For the velocities recorded at the Fort Bliss sites this results in an exposed distance slightly greater than one tank length.

(5) Comparing observer and laser data from this test shows that the micro-cover of the terrain greatly influences the LOS. Within the same type of terrain dune size or vegetation density can greatly affect the size of the LOS breaks. Some of the differences between observer and laser data can be explained by allowing the laser data to have an error of approximately one tank length. However, other discrepancies can only be explained by the additional error of judgment and perception on the part of the observer.

8. SUMMARY OF RESULTS. As has been demonstrated by the various trial plots presented, the intervisibility between a given defender and an attacking force is highly dependent on three factors: terrain, defender position, and tactic employed by the attacking force. In more open terrain the defender sees roughly the same target array sequence regardless of the tactic employed by the approaching force. Tradeoffs begin to occur when the terrain is more wooded. In this case the attacker using the terrain features to their maximum cover advantage results in shorter and choppier periods of exposure. However, the attack momentum is considerably slower. Use of a rapid, straightforward movement to the objective results in longer individual exposure, but the approach takes much less time. A defender who is in a flanking position relative to the attacking force appears not only to have an increased view of the playing area but also is afforded greater intervisibility with the player force. Comparison of laser LOS data with that recorded from observers at the same positions shows that intervisibility data from observers should be used very carefully. If these data are to be used in an engagement analysis, it should be remembered what type of system it is being applied to. The laser data point out breaks in LOS that could conceivably affect the weapon system being analyzed, especially if it requires continuous line of sight until impact. CACDA will conduct a further analysis to examine what effect the difference of target intervisibility recorded by a laser and an observer has on the engagement opportunities of specific weapon systems as the TOW, Laser Beam Rider (LBR), HELLFIRE missile system, CLGP, and a M60A1 main tank gun.

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